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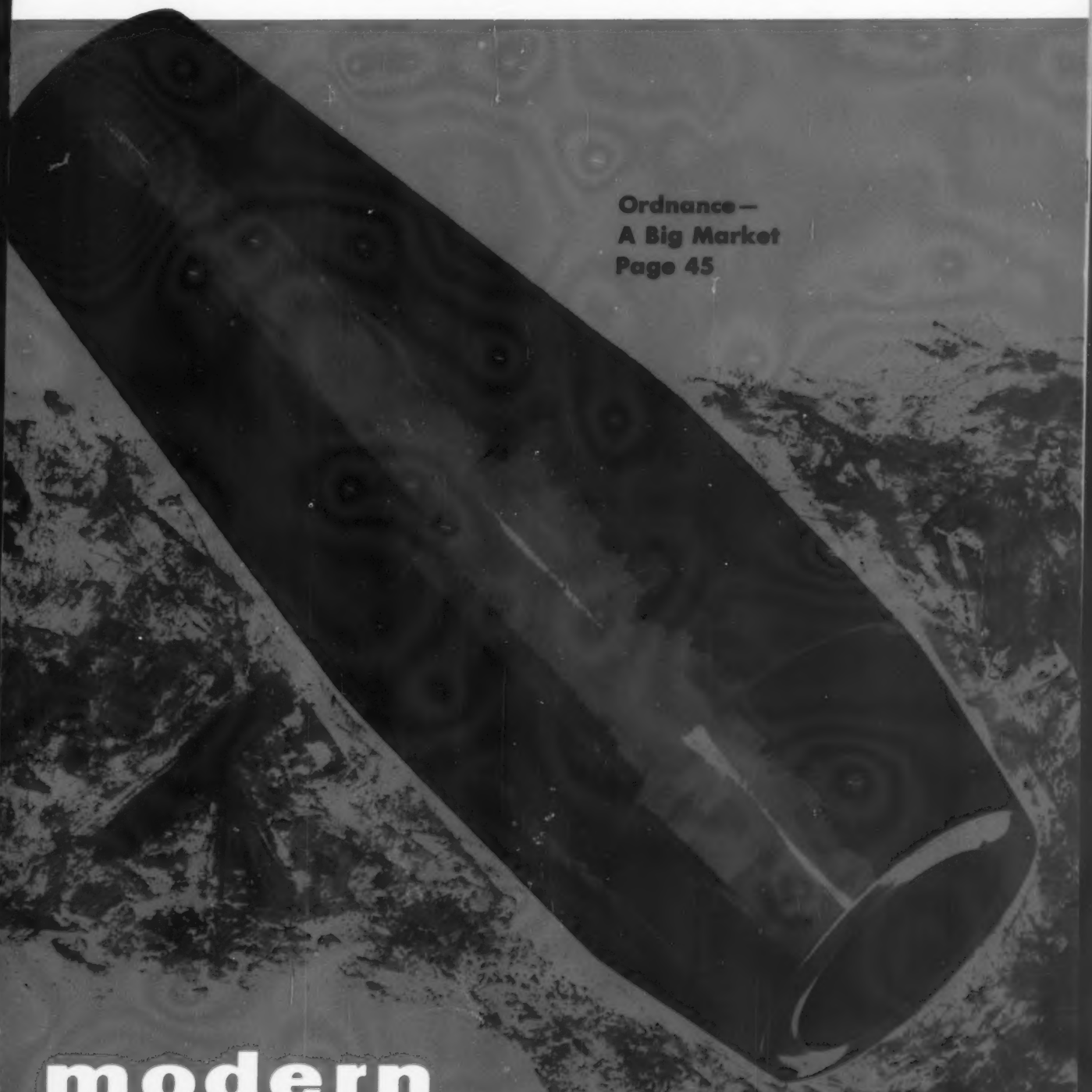

**Ordnance—
A Big Market
Page 45**

modern castings

the technology-for-profit magazine

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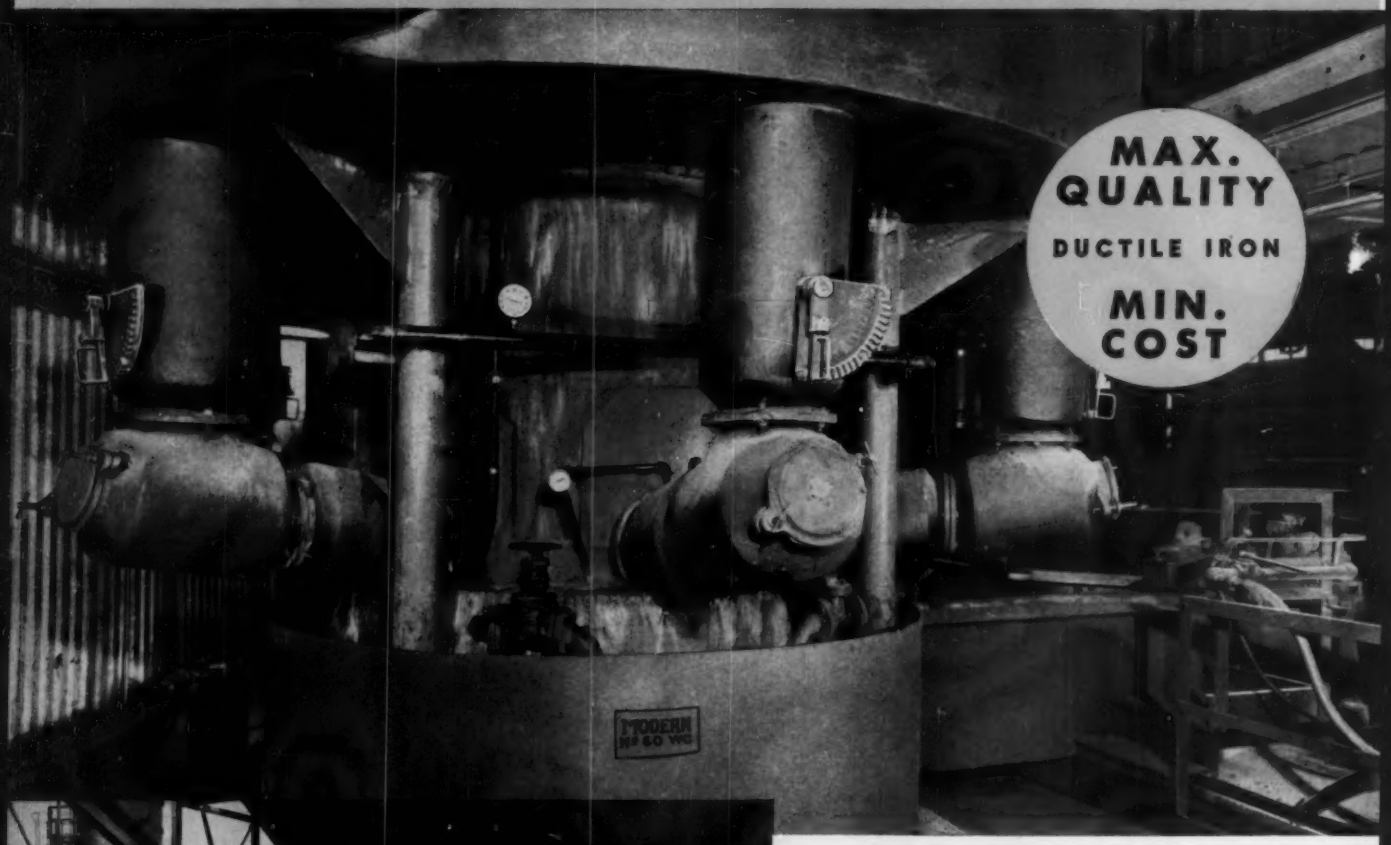

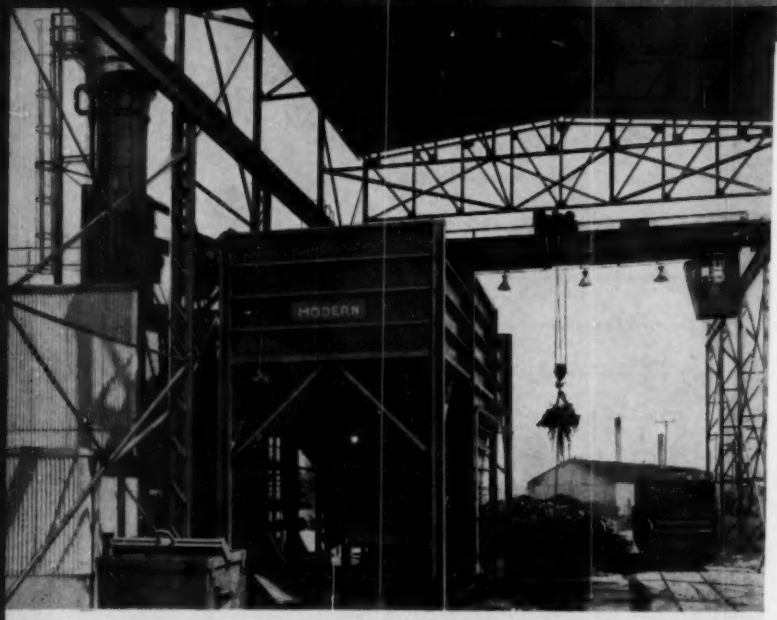

Skip charger with 42" x 42" small-cone bucket. 7½ ton, 50 ft. span magnet crane services the bins.

Overhead traverse is synchronized with conveyor for electrified pouring.

• CHARGING . . . • MELTING . . . • POURING!

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MODERN

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Circle No. 122, Pages 143-144

November 1961 Vol. 40, No. 5

modern castings

metalcasting "technology-for-profit"

COVER

Drawn by CHARLES ROTH. Pearlitic malleable shell for 81 mm mortar cast by Albion Malleable Iron Co. New defense program presents huge potential market for castings. See page 45 for details on how castings can play a vital role in this field.

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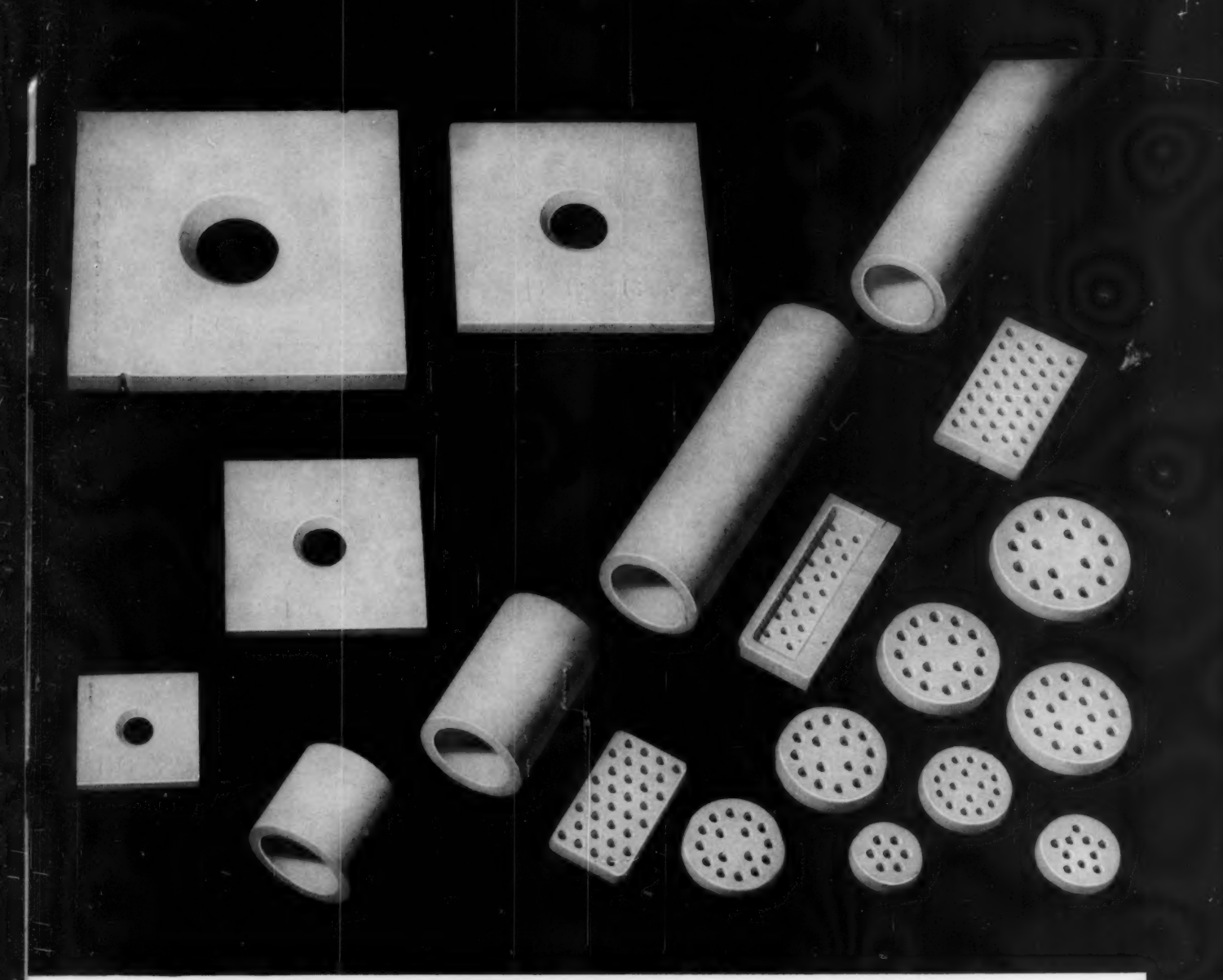

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GENERAL MANAGER
WM. W. MALONEY

Let's look at . . .

"MUST" READING FOR NOVEMBER

H. E. Green

I WOULD LIKE to recommend a number of articles for your special attention this issue. They're timely. And you'll find them significant.

First, there's the special market opportunities report. It is on casting for defense. Spearheading this vital study is Major General W. K. Ghormley. As commanding general of the U. S. Army Ordnance Special Weapons-Ammunition Command, he is intimately concerned with research and development activities. See page 45 for a full picture!

Second, is a key article on ductile iron and shell molding. Arthur Adams and Harold Grant, Ford Motor Co., tell how millions of fault-free crankshafts are coming out of the factory. MODERN CASTINGS has been working for more than a year to detail, exclusively for you, this significant development. You'll find it on page 52. It has just been released for publication.

Third, but not least, is the newest report of MC's Trends Panel. Once again these bellwether metalcasters and suppliers tell you what they believe is ahead for 1962. Their opinions and counsel cover many vital areas:

—How much business

—Where this business will come from

—Accelerating trends in metalcasting

—Marketing know-how for metalcasters

—Executive and plant-worker training needs

As you no doubt have guessed the business forecast is good, the challenge great. See page 50.

At this time I would particularly like to thank the metalcaster and supplier members of this industry panel. Their service has been a tremendous asset to all. Their thinking and opinions have been penetrating and deeply helpful. We hope they'll all be able to continue with their advice and guidance in 1962. All metalcasting is indebted to them.

Harold E Green

HOUGHTON FOUNDRY SAND BINDERS

New development in sand binders can put the magic of catalytic polymerization to work in your foundry

**CURES "READY-TO-POUR" IN 6 TO 8 HOURS WITH NO BAKING.
PRODUCES NO IRRITATING FUMES.**

New Quik-Sett NB is a concentrated furan-type resin binder for large sand molds and cores that cure thoroughly at room temperature. Sand surfaces are exceptionally smooth and hard, producing excellent surfaces on castings. Because it cures by catalytic polymerization, without oxidation or baking, handling is reduced to a minimum—time and money are saved.

No irritating fumes

Most furan-type binders available to date have produced a strong, irritating formaldehyde odor because the formaldehyde was loosely combined with the resin. This objectional characteristic has been eliminated in Quik-Sett NB through precise resin control and special compounding procedures. The result is a concentrated resin that produces no persistent odor during working and curing.

Cores and molds made easier and faster

Total mulling time is only 2 to 7 minutes producing a mix with excellent flow characteristics. Because the mix flows readily, no ramming is required in setting up the core or mold. Little more than hand tucking is needed to fill all voids in the pattern.

Since cores and molds of Quik-Sett NB have superior early strength, rodding is drastically reduced. Usually only a bottom and top web, to anchor hooks, is ample.

Other features of Quik-Sett NB

- Simplified binder-catalyst process
- Fast, controlled curing
- Low gas content eliminates pin holes
- Surface density minimizes penetration or burn-in
- Accurate dimensional stability
- Excellent storage characteristics

This huge core, made with Quik-Sett NB and weighing 1250 lbs., was started in the morning and was ready to pour before the "whistle blew" that evening.

GET THIS BULLETIN

QUIK-SETT NB (No Bake)

Get the whole story on this new development in no-bake sand binders. Whether or not you have used or are now using this type of material, you will be interested in what Quik-Sett NB will do—the many advantages it has over conventional no-bake binders. Write for your copy of the new bulletin describing Houghton Quik-Sett NB. And if you wish, we'll gladly *show* you what it will do in your foundry—on one of your jobs. E. F. HOUGHTON & CO., 303 W. Lehigh Ave., Philadelphia 33, Pa.

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Circle No. 124, Pages 143-144

Looking at Business with Modern Castings

FARM EQUIPMENT

Farm equipment sales are on the increase due to higher government supports and rising prices for farm products. Despite the cut in crop acreage, good weather and increased use of fertilizers still produced larger yields per acre. New equipment is needed to handle the unprecedented output. Low dealer inventories have made the upswing in purchases felt almost immediately. Some dealers already report shortages of equipment.

TEXTILES

Faster tax write-offs on some clothing making machinery is expected to aid in modernizing the industry. Manufacturers will be better able to meet foreign competition and provide additional jobs. The authorization was speeded at the request of President Kennedy.

CONSTRUCTION

Sales of shell homes continue to rise--up 25 per cent from a year ago. Total sales are anticipated at 100,000 or up 20,000 from last year. Although accounting for only 8 per cent of the housing market, shell homes have doubled in the last five years. Many large companies, including builders of pre-fab homes are coming into the market.

AUTOS

Compacts continue to make inroads in the U. S. auto market. Thirty more compact models are offered this year--a total of 121. The industry offers an over-all total of 278 models (standards and compacts)--an increase of 18 over last year.

DEFENSE

Emphasis on mobility of men and equipment in the new defense effort is expected to add an additional market for millions of pounds of aluminum. Early acceptance of equipment in the prototype or development stage could make further increases. The impact is expected to be felt early in 1962. Typical increases are in tanks, cargo craft, cargo and transport planes, aircraft and missiles, naval deckhouse structures, ships, and landing craft. See page 45 for the MODERN CASTINGS report on the use of castings in the Ordnance program.

COMPETITION

The welding industry predicts to be a $2-billion industry by 1970--doubling its present sales within the decade. Welded construction of steel buildings is a major factor in this expansion with other increases coming in construction of bridges and auto bodies.

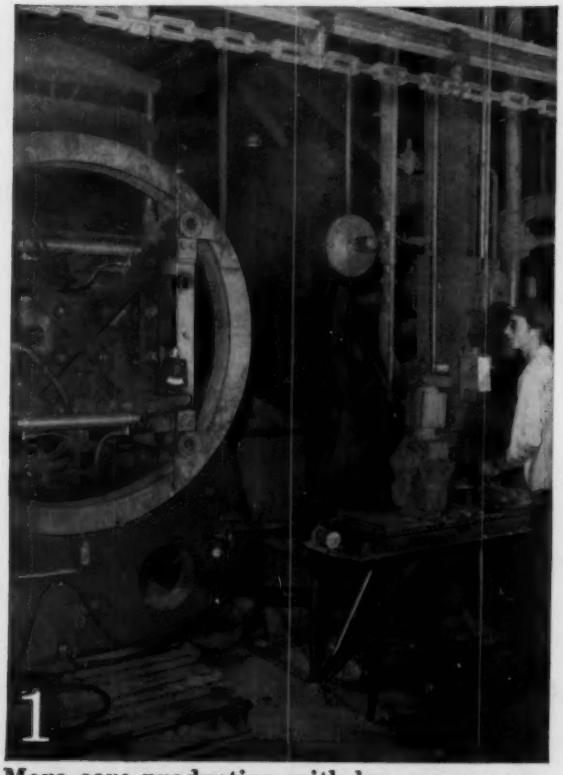
PRICES

Lower prices on industrial and consumer goods are in evidence despite recovery from the recession. Heavy competition is the reason. Many price increases are being put into effect but a downward trend over-all is noted.

John Deere Reports on Shalco Shell Core Blowing . . .

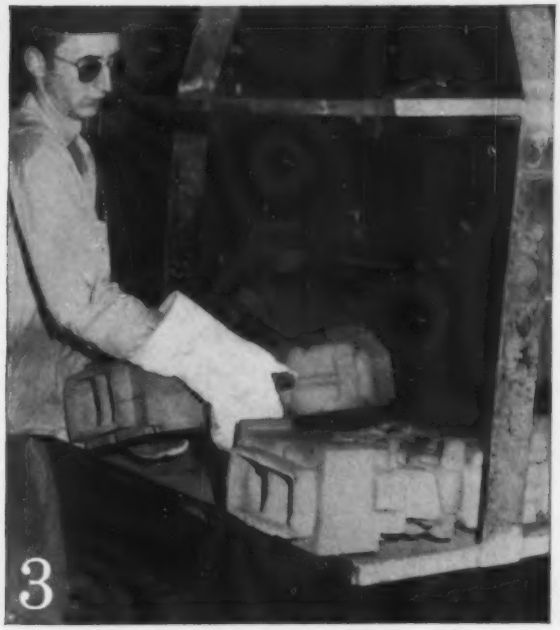
One piece, completely hollow precision shell cores cut cost of heavy castings

At the John Deere Tractor Works, Waterloo, Iowa, two Shalco U-360 Shell Core Blowing Machines have slashed production costs of large heavy castings for John Deere "New Generation" Tractors. In the photos, follow the production of Shalco one piece, completely hollow precision shell cores—in sections, over 1" thick! See how they help this famous farm implement manufacturer produce heavy engine block castings . . . faster, more economically. Then, consider this: John Deere's experience is typical. The economical production of large precision cores for heavy duty castings is duck soup for Shalco U-360's. Everywhere, cost-conscious foundrymen are taking advantage of this unique capability and the unmatched service and engineering experience that backs it up. You'll profit by getting complete details. Call, write or wire.



More core production with less manpower

—The two Shalco U-360's produce up to 120 precision shell cores per hour (1). With conventional methods, equal output required twice as much manpower! Completed cores are exceptionally strong, but lightweight and easy to handle (2).



Less core processing and handling expense, less cleaning, less material —Shalco one-piece cores have eliminated costly, time-consuming "halving", Result—no core drying, and baking, a reduced requirement for production floor space, less handling, no seam finishing. Shalco cores are amazingly smooth and accurate . . . are completely hollow and at least 33% lighter than solid cores. (To meet John Deere's unusually high specifications, critical areas of these particular cores are sprayed to further assure highest casting quality and strength.)

Last phase of Shalco savings . . . highest quality castings . . . for less — Six Shalco cores (one per engine cylinder) are assembled and the mold is ready for pouring (4). No chance of misalignment here. The Shalco Shell Core Blowing Machines produce identical, precision cores that fit together quickly, easily . . . every time.

Removed from the mold, the rough casting is ready for shakeout (5). Thanks to the excellent collapsability of Shalco Shell Cores, shakeout is complete and there's little need for cleaning.

And here's the completed casting (6). Due to the precision and consistency of Shalco Shell Cores, the casting has no sand inclusions. This cuts cleaning time from hours to minutes and greatly reduces finish machining. Less casting stock is wasted, the life of finishing tools is extended . . . and further savings are realized through an additional reduction in manpower.

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COKE — COAL — COAL CHEMICALS

Circle No. 126, Pages 143-144

Around the World with Modern Castings

CANADA

In a search for non-nuclear uses of uranium which is in abundant supply (see Modern Castings, October, page 41), the Department of Mines and Technical Surveys has discovered benefits resulting from its addition to plain carbon steels. Such steels show superior resistance to chemical attack when immersed in the electrolyte of electrolytic carbide extraction cells and in oxygenated solutions of strong acids. Small additions of uranium increase fatigue strength, stress rupture time, and rupture life at elevated temperatures. Uranium is added to molten steel by wrapping small pieces in aluminum foil and plunging them into the ladle. Now that the search is on we expect to hear about increasing uses for this once rare metal.

EAST GERMANY

Severe pitting of low carbon steel castings poured into shell molds has been a serious problem in East German foundries. An extensive research program revealed the defect could be eliminated by adding five per cent ground and sieved lime to a shell sand mix containing four per cent resin. These recommendations agree with work done in this country several years ago. The substitution of forsterite for silica has also helped solve this problem in the U. S.

WEST GERMANY

Aluminum, Ltd., big Canadian aluminum smelter, has acquired the Uphusen Works—a modern aluminum foundry in West Germany near Bremen. The foundry has facilities to produce sand, permanent mold, and die castings. Aluminum, Ltd.'s total foundry capacity in Germany is now close to 10,000 tons per year. This is one way of taking care of the extra supply of aluminum.

INDIA

"The Ferro-Alloy Industry in India" will be the subject of a symposium in February 1962 at the National Metallurgical Laboratory, Jamshedpur. Technologists, metallurgists, and research scientists in India and abroad were invited to attend and contribute papers. The extensive expansion of steel production capabilities called for in the Third Five Year Plan means a corresponding need for more ferro-alloys. The Symposium will cover: (1) Raw materials available in India; (2) Beneficiation of these raw materials; (3) Different types and grades of ferro-alloys needed; and (4) Utilization of by-products generated from ferro-alloy production.

ENGLAND

The second quarter of 1961 indicates the overall rate of cast iron production was the same as, or slightly better than, that of the previous quarter. With the exception of ingot molds, where the reduced demand for steel is having its effect, there have been only

(Continued on page 14)

Cost-reducing Facts for Foundrymen:

Here's the inside story on are reduced, production is

A FEW BASIC FACTS

Erosion of the lining, coke ash, and adhering sand on returned scrap are sources of the slag obtained in the acid-line cupola. These materials are primarily silica or SiO_2 (silicon dioxide), that, even with considerable impurities present, have a relatively high melting point . . . possibly exceeding temperatures of 2900° F. Pure SiO_2 does not fuse until the temperature reaches approximately 3100° F.

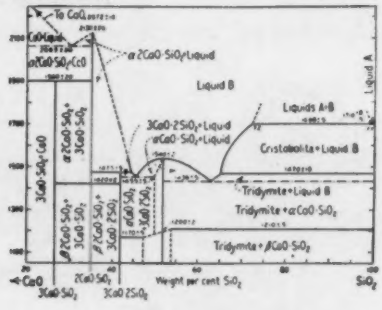
How to remove slag

Undesirable slag constituents must be transformed into a liquid that will flow readily at normal operating cupola temperatures below the melting zone or at temperatures exceeding 2400° F.

One "recipe" that attempts this is the addition of limestone to the cupola. As the limestone drops into portions of the cupola where temperatures rise over 1650° F., it is calcined to lime or CaO with considerable loss of heat. It is hoped that lime so formed will combine with the SiO_2 and form a lower melting temperature slag. (See Fig. 279. The melting temperature of the slag decreases to a low of about 2610° F. with increasing additions of CaO up to 35 mol %.)

This temperature is not very low for cupola operation. Also, conditions frequently occur that prevent the melting point of the slag from approaching that temperature. Failure to reach and maintain this temperature results in insufficient slag fluidity. It becomes viscous or pasty and chokes up the intensity of the coke . . . and in the areas chilled by the tuyeres, BUILDS A BRIDGE.

Fig. 279 — Equilibrium diagram for CaO-SiO_2 system (Hall and Insley, *Journal of American Ceramic Soc.*)



Three factors cause bridging

(1) High silica content in localized areas because of lining erosion or charge variations producing a higher slag melting temperature (2) Cold spots in cupola due to variations in charge concentration (3) Low temperature areas in the cupola caused by channeling of air through the charge and a non-uniform oxidation zone across the cupola.

Pictured, left, after bottom was dropped, is an actual photo of a cupola in which bridging occurred.

Right, a clean cupola, after bottom was dropped, in which charge contained Cleveland Cupola Flux.

8633-CF

how bridges in cupola operation increased...time and money saved

HOW TO CURE BRIDGING

Cleveland Cupola Flux avoids bridging problems by lowering the fusion point of the slag. Used regularly in the charge in the prescribed amounts—one full brick for each ton of metal charged—melting point and viscosity of the slag are lowered sufficiently to avoid bridging difficulties, even in high silica and low temperature areas.

Ingredients of Cleveland Cupola Flux are prepared and balanced to accomplish this without stack losses or high basic concentrations that attack the acid lining. Melting point of the slag is lowered hundreds of degrees so that it flows rather than sticks. The charge flows uniformly and is kept under proper control, resulting in balanced behavior.

These same ingredients are balanced to provide both the lower fusion temperature with fluorspar (CaF_2) and lime or CaO obtained from limestone. Fig. 713 shows the effect of fluorspar on the melting temperature of lime. Fig. 690 shows its effect on the slag melting temperature from a combination of SiO_2, CaO and CaF_2.

Serious bridging can stop all downward flow of the charge and force the operator to drop bottom! Slight bridging can cause irregular rates of fall of the charge in the cupola! Bring channelling of the gas and erratic operation!

Cleveland Cupola Flux reduces or eliminates bridging, helps increase production . . . saves you time and money! For more information on this or other fluxing operations, send your inquiries to our new Technical Service Department at the address below.

Fig. 713— System CaF_2—CaO. B. Karandyeev, *Z. anorg. Chem.*, 68.

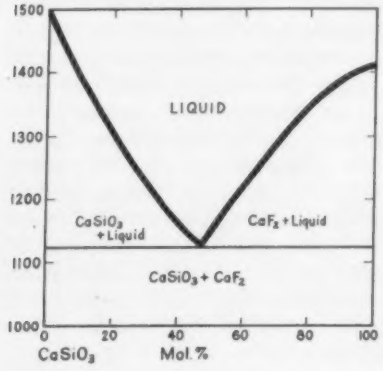
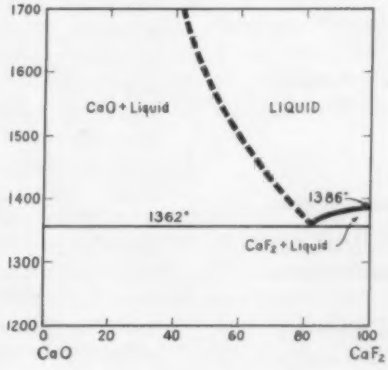


Fig. 690—System CaF_2—CaO. W. Eitel, *Zement*, 27, 455-59, 469-72, (1938).



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The CLEVELAND FLUX Company

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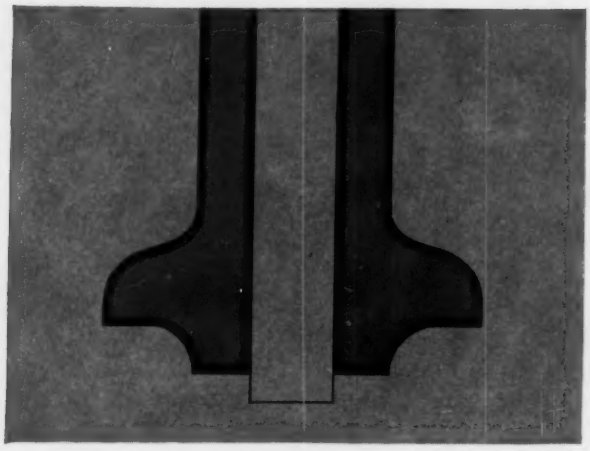
Manufacturers of Iron, Semi-Steel, Malleable, Brass, Bronze, Aluminum and Ladle Fluxes...Since 1918

Circle No. 127, Pages 143-144

M&T

OREFRACTION

Zircons give smoother surfaces



Orefraction Zircon provides a smoother finish and greater casting detail because of its finer grain and non-wetting characteristics.

It also withstands higher temperatures. As a result, use of zircon sand for facings, molds and cores avoids roughness and burn-in at heavy metal sections. A zircon core and mold wash provides an *exceptionally* smooth surface. You get a better casting, and do less cleaning.

To these benefits, add the greater dimensional control offered by zircon sand molds for critical castings and cores. And their resistance to erosion. And the "directional" solidification from selective facings of zircon.

Contact your local distributor of famous M&T Orefraction Zircon Sand and Flours. Ask us for his name.

M&T OREFRACTION PRODUCTS

METAL & THERMIT CORPORATION General Offices: Rahway, N.J.
In Canada: M&T Products of Canada Ltd., Hamilton, Ontario.
Circle No. 128, Pages 143-144

(Continued from page 11)

marginal changes in the different sections of the industry. Slight increases in the rate of output in the automobile, railway equipment and general engineering sections have been balanced by an easing demand for building and domestic castings.

The underlying trend suggests continuing firm trading. The engineering industry has full order books. There is a high rate of activity in building and a steady demand for commercial vehicles and tractors. Less predictable conditions may exist elsewhere, since the steel industry is currently producing at a reduced level and the demand for domestic goods and for motor cars cannot fail to be affected to some extent by the latest increases in purchase tax.

JAPAN

Japan has about 5,000 operating foundries — almost as many as the United States. Admittedly the total output is far below that in this country. In 1959 some 2,192 iron foundries produced only 1,483,000 tons of castings, compared with 12,300,000 tons shipped by U. S. foundries the same year.

Some 90 per cent of Japan's casting production is gray iron in contrast with 78 per cent in the States. In 1959, the Nipponese foundry industry also produced 100,273 tons of malleable iron, 55,526 tons of copper-base castings, and 26,052 tons of light metal castings.

Annual productivity per worker in gray iron foundries was 17 tons. Hourly wages range from 13 cents in cast iron pipe shops to 43 cents in captive automobile foundries. This works out to be $40 to $70 a month wages for worker in gray iron foundries. The advantage gained from low wage rates is counter-balanced by low worker and plant productivity.

UNITED STATES

Paga Molds, Inc., Augusta, Ga., has signed a licensing agreement with Compagnie de Pont-a-Mousson, Nancy, France, for exclusive U. S. rights to a new ductile iron ingot mold process. With the new mold, steel ingot production costs are reduced considerably as the result of longer mold life—two to three times that of conventional gray iron. Overall weight of molds can also be appreciably reduced since ductile iron has a higher strength-to-weight ratio. Paga plans to make licenses available to other foundries interested in producing these ductile iron ingot molds. With over 2,246,500 tons of gray iron ingot molds being made a year this is a market well worth going after by ductile producers.

Metalcasting and Washington

Some Broad Views

Both government and industry economists are forecasting a great expansion in the economy ahead—billions of dollars in new plant and equipment investment by U. S. industry . . . But the Administration appears uneasy at the same time . . . Two leading spokesmen — Commerce Secretary Luther H. Hodges and Labor Secretary Arthur J. Goldberg—are engaged in a round of speeches to industry groups asserting that the Administration is not anti-business. Its programs they contend are leading to an improved economy.

For all of their admiration for the Administration "programs," in their speeches, Cabinet members have been urging industry to step up the economy, without making clear what it is that industry should do. There was this comment by Hodges:

"I believe that generally speaking America is not showing the same degree of business initiative and business drive which characterized earlier periods in our economic history . . . This conclusion is inescapable when I note the degree of obsolescence in our industrial plant . . . I am not making a blanket charge that American industry is unimaginative or unproductive . . . Our half-trillion GNP is impressive indeed . . . Our standard of living continues to be the envy of the world . . . But I cannot help feel that there are too many soft spots, too much self-satisfaction with the status-quo . . . (The) Objective of an $800 billion economy in less than 10 years is a realistic one. But we are going to have to work for it."

Withal, Mr. Hodges notes a "strength of recovery" from the recession, and that "business is good." But as to the recovery, he points up only what "we" (the Administration) has done to revive the economy.

R&D on the Upswing

The metal products industry is among those which vastly increased outlays of funds for performance of research and development recently. Release of an intensive study of R&D in American industry by the National Science Foundation revealed this news . . . From expenditures of $92 million in 1956, the metal products industry R&D funds increased in 1960 by 37 per cent, to $126 million . . . Of the 1960 outlay, $54 million was provided by the Federal government, somewhat less than in the year before, and more than made up for by increased company spending.

An estimated total of 11,800 industrial firms used R&D in 1958. Of these, 10,600 with less than 1000 employees accounted for 90 per cent of the total. The relatively large number of companies with less than 1000 employees accounted for only seven per cent of total funds for R&D performance, whereas the relatively small number of companies with 5000 or more employees accounted for 84 per cent of R&D funds in 1958.

The cost per R&D scientist or engineer in the metal products industry in 1958 was $25,600 . . . This was about midway in a wide variation, ranging from $16,400 in the food industry, to $52,500 in the motor vehicle and other transportation equipment industry.

At Session's End

The 87th Congress, in its first session, had before it many legislative proposals affecting business . . . It passed an amendment to the wage-hour law bringing many more workers under the minimum wage and overtime provisions of the law . . . Otherwise it skipped proposed measures both helpful and not so helpful to industry, nearly all of which came under suggested tax revisions.

On tap this year again was the bill to provide some tax relief, particularly for small businesses, on income reinvested in capital outlay or inventory . . . another would provide tax relief for small business owners and other self-employed persons on investment in retirement plans . . . The latter's purpose was to give such persons the same tax advantages enjoyed for years by employed persons and corporate executives . . . It moved further than in earlier sessions, getting passed by the House and reported out by the Senate Finance Committee, but this was as far as it got.

The "reinvestment" measure did somewhat better than in earlier years, at least in having had more attention, but that was all . . . It was under two handicaps. (1) It was part of the Administration's recommended overall tax bill which ran into severe trouble in Congress, and (2) It was criticized by industry representatives and academic economists who asserted that far preferable would be an improvement in depreciation tax allowances.

. . . the Administration is firmly convinced that tax reform is necessary if we are to have sustained, high-level economic growth. We cannot have this growth and full employment for an expanding labor force if business profits are not adequate."

By W. R. Fingal

comparative tests prove Wheelabrator steel abrasive costs less

Typical test based on use of S-550 Shot, .017" Removal Size, 20 H.P. Motor, Nominal Abrasive Loss	Consumption Lbs. Per Hour	Cost Per Wheel Hour
WHEELABRATOR STEEL SHOT	7.4	70¢
STEEL A	9.9	89¢
STEEL C	8.55	79¢
STEEL D	9.25	81¢
STEEL R	10.7	91¢
MALL. G	13.5	$1.01
MALL. P	18.5	$1.20

PROVIDES LOWEST TOTAL BLAST CLEANING COSTS

In over 5000 field and laboratory tests, top quality Wheelabrator steel abrasive has demonstrated its ability to provide lowest possible total blast cleaning cost. True abrasive value is determined by the amount of work it will do in a given time, the quality of the finish, and the cost of performing it. Wheelabrator steel abrasive excels in all three factors as a result of its high hardness, its uniformity from pellet to pellet, and its toughness and strength. Wheelabrator Steel Abrasive can make a big dent in your total cleaning costs. Write for our Handbook of Blast Cleaning Abrasive Performance, full of vital information to help you control abrasive consumption and cleaning costs.

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Circle No. 130, Pages 143-144

From and For the Reader . . .

FLUORSPAR NOT DANGEROUS

Are there any dangers involved in the use of fluorspar in the cupola? What are the possible dangers of dermatitis or crop damage?

B.H.A.

Editor's Note: There is no record at AFS of foundries having dermatitis problems or of crop damage because of the use of fluorspar. This is because most of the fluorspar melts and is retained in the slag; and very little particulate matter is discharged through the stack. Even the handling of cold fluorspar does not cause dermatitis except in people high susceptible to it.

A midwest steel plant receives shipments of fluorspar in car-load lots. It is used in the open-hearth furnaces melting 250 tons per heat in the proportion of about ½ per cent. Neither in the handling or the melting have they experienced dermatitis or property damage even though they use about ten times the amount used in cupolas.

Inhalation of the dust rarely results in systemic poisoning except where exposure is to massive doses and for long periods. This is because fluorspar is not very soluble in body fluids and because the discharge action of the cilia in the nose and throat is effective in eliminating the dust from the respiratory tract. Under conditions of such severe exposure a first sign of the poisoning is mottling of the teeth. This is called dental fluorosis.

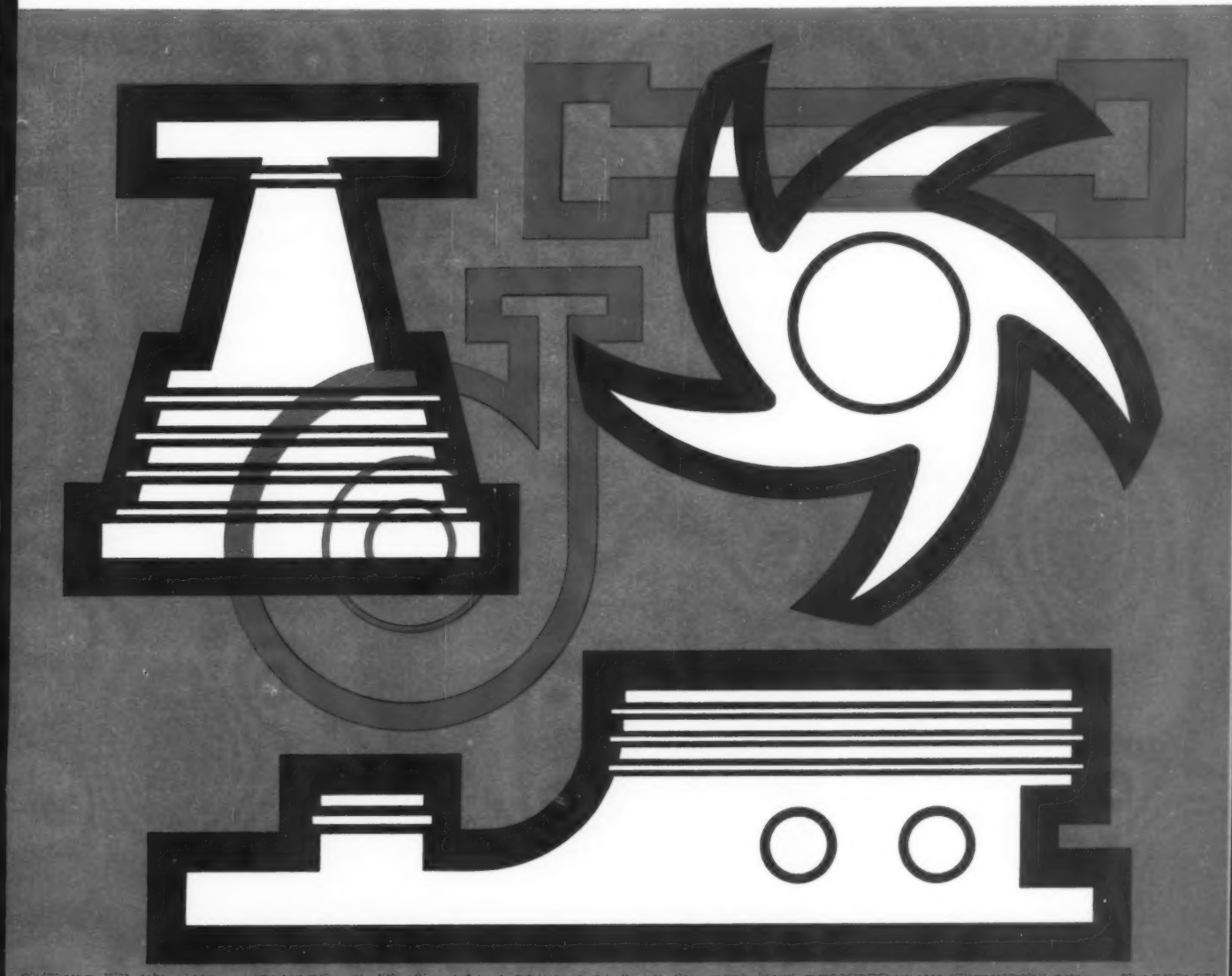
The biggest problems to date are in areas near aluminum production plants and particularly fertilizer plants. In the latter case, crushing operations cause a massive discharge of fluoride powder which settles on crops.

CARBON MONOXIDE CHECK

Our hygiene department reports carbon monoxide readings in excess of the maximum allowable concentration. The trouble can be traced to lift truck operation which is spotty and seasonal. The area is rather large and the concentration excess relatively minor.

Can the problem be controlled

(Continued on page 24)



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QUALITY CONTROLLED GRAY IRON CASTINGS

SOUND • CLEAN • EASY TO MACHINE

FERROCARBO BY CARBORUNDUM

FERROCARBO-Treated Gray Iron assures

Quality castings can now be produced, through improved structure control, by the addition of Ferrocarbo Briquettes to cupola melted gray cast iron. This unique deoxidizing agent improves cupola melting practices by eliminating many of the casting difficulties of untreated iron. Ferrocarbo-treatment helps reduce costs for the foundry **and** the casting buyer. Misruns and rejects are minimized; fluidity is increased. Castings show improved machinability, and superior physical and mechanical properties.

RAW MATERIAL SAVINGS. The highly reactive nature and reduced chilling tendency of Ferrocarbo-treated iron permits the

FERROCARBO®Keeps foundry costs down, production up

use of more scrap in the charge. Further, the elimination or reduction of other charge ingredients is often possible.

MISRUNS REDUCED. Iron deoxidized with Ferrocarbo is more fluid at casting temperatures than untreated iron. It flows more readily into thin sections or complicated molds. You get better castings . . . fewer misruns. Some foundries report up to 50 per cent reduction in misruns after using Ferrocarbo in the charge.

FERROCARBO®—the only cupola deoxidizer with

stronger...cleaner...more machinable castings

Complete, controlled disintegration of Ferrocarbo Briquettes is accomplished in the melting zone. This means thorough reaction in the cupola providing a consistently uniform operation.

IMPROVED MACHINABILITY. Ferrocarbo-treated gray iron is free from segregations, inclusions and deep, hard, chilled spots. It is more easily machined . . . increases the life of cutting tools up to 35 per cent . . . often permits faster machining speeds.

You can increase the tensile strength of castings for your customers as much as 2,000 to 2,500 lbs. per square inch when you

FERROCARBO® Helps you get and keep customers

treat your gray iron with Ferrocarbo. The castings are finer grained, denser, stronger.

The elimination of graphite, sulphide, phosphide and carbide segregation in Ferrocarbo-treated gray iron removes planes of weakness which cause cracking and wear under conditions of high temperature and friction. In addition, the improved structure provides a better enameling surface.

an expanding agent, a catalyst, and a slag activator

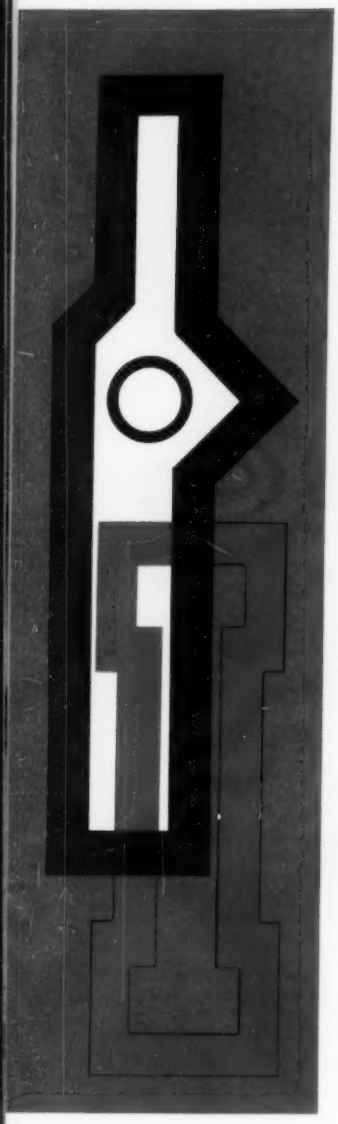
FERROCARBO® BRIQUETTES

SPECIFICATIONS AND PACKAGING

The size and weight of the briquette was established for ease of handling and rapid, accurate calculation of proper percentage of addition. Approximate Size and Weight: 3-1/2" x 4-5/8" x 4-3/4"; 5 pounds.

Available on standard pallets of 24 cartons, 16 briquettes per carton; also, smaller pallets and individual cartons. Waterproof covers and lifting slings as required.

Ferrocarbo Briquettes can be stored indefinitely without deterioration.



FERROCARBO® BRIQUETTES

TECHNICAL COUNSEL

■ Carborundum welcomes your inquiry and offers the assistance of its representatives to help you solve your casting problems. Ferrocarbo representatives are practical foundrymen — usually graduate metallurgists — expertly qualified to assist you in solving your foundry problems and increase your production efficiency — with Ferrocarbo.

■ Complete laboratory facilities are available for scientific evaluation of Ferrocarbo-treated irons from your foundry.

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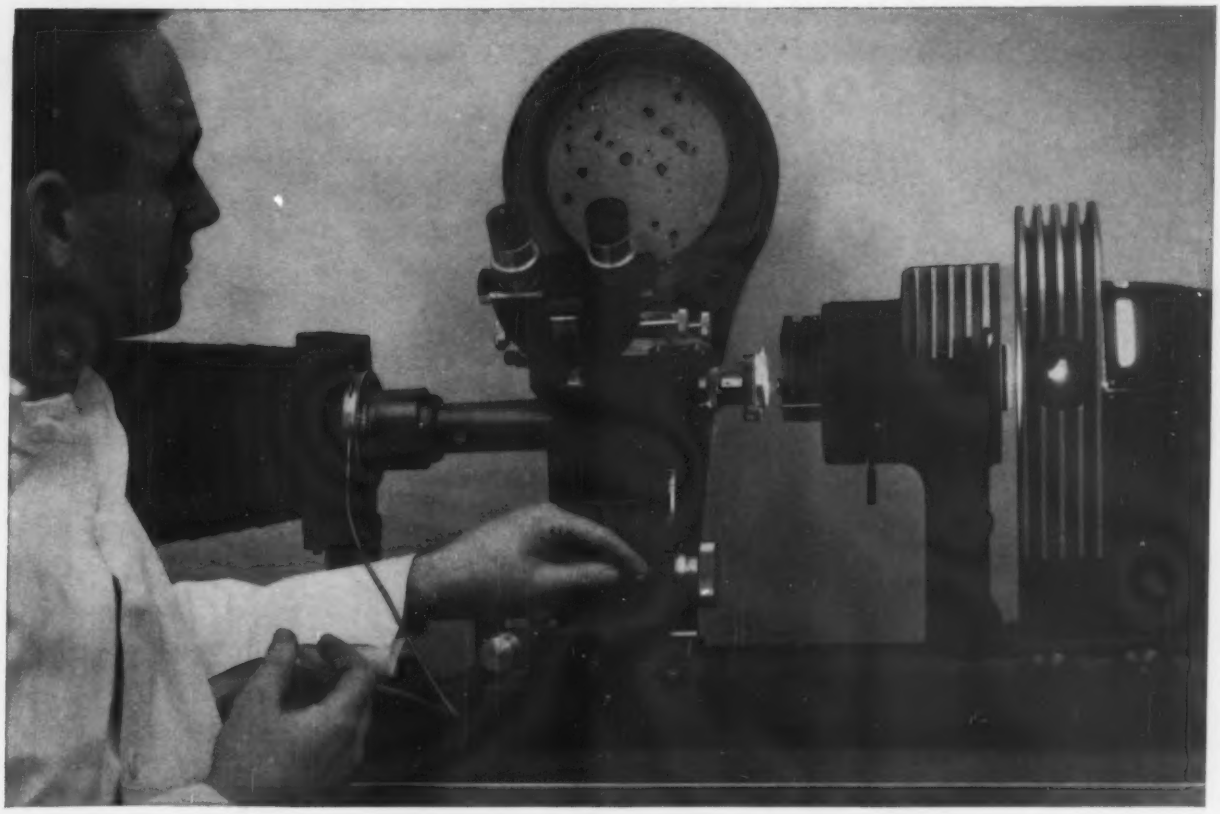

SEARCHING FOR A BETTER WAY TO MAKE DUCTILE IRON

Sorbo-Mat Process Engineers can improve your foundry techniques and keep costs down . . .

Ductile iron is one of the most significant metallurgical developments in well over one hundred years and engineers throughout industry are specifying this versatile material for more and more applications. However, despite advances in foundry techniques and in processing materials many foundries experience difficulty in producing ductile iron castings that live up to specified claims. Not every foundry has the metallurgical know-how and facilities, nor do they use the necessary controls to achieve the correct arrangement of the spheriodal form of graphite in a steel-like matrix which gives this remarkable metal its unique combination of engineering properties including exceptional toughness, ductility and high strength.

Sorbo-Mat Process Engineers are a group of metallurgical and foundry engineers skilled in the newer methods of manufacturing dependable ductile iron and cast metals at the most competitive prices.

Though essentially concerned with the metallurgical operations of producing uniformly sound castings, Sorbo-Mat services embodies instructions in the applications of new foundry techniques and continued guidance in all phases of foundry operations to insure efficient, low cost production.

If you are searching for a better way to make ductile iron . . . or for that matter . . . any metal casting . . . and at the same time keep your costs in line, write to Sorbo-Mat Process Engineers for more information. Many major foundries throughout the United States and Canada have solved their casting problems with Sorbo-Mat.

CONTROLLED SPECIFICATION CAST METALS
STRUCTURE STRENGTH SERVICE
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Controlled Specifications Cast Metals

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. . . a matter of built-in resilience in BLACK HILLS BENTONITE

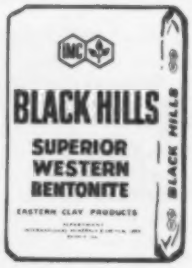
It takes strength and character to stand up under forceful treatment. And a blend of well-balanced bond clay qualities to hold up without cutting corners.

Black Hills excels over any other type of bond clay in this vital characteristic. It's really tough! Result: less trouble with difficult lifts . . . less breakage of corners and edges.

You get high green strength and high hot strength, too. Used as directed, it also gives you high permeability with a minimum amount of tempering water. There's less material to handle, less dead clay left to be removed, less work in the long run.

And you get highest dry strength — added insurance against cuts and washes, particularly in steel foundry practice.

For unbiased and cost-free recommendations on Black Hills Bentonite, or any other bond clay in IMC's complete product line, get in touch with our service engineer who calls on you, or write direct.



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FS-1-2

Circle No. 134, Pages 143-144

LETTERS

(Continued from page 16)

with a device attached to lift trucks similar to that being developed for automobiles in the Los Angeles area? Have you any reference material on ventilating for the dilution of carbon monoxide fumes?

D.E.D.

Editor's Note: The three major automotive companies are working on burners. One has developed a catalytic burner which will oxidize hydro-carbons only — not carbon monoxide. The second has a burner which will handle carbon monoxide too. It will cost $200 when commercially available and operates at 900 to 1200 F. The third has a non-catalytic after-burner operating between 1500 and 1600 F. It will cost about $300. Apparently none are on the market yet.

Dilution formulae can be found in the Governmental Hygienists' "Industrial Ventilation." The maximum allowable concentration of 100 PPM provides for a good margin of safety.

Maximum allowable concentrations should be reasonably interpreted. Findings should not be based on a grab sampler collecting a small amount of air and depending on a color match.

A check should be made with a gallon-can sample which is titrated with iodine pentoxide — the only really accurate method of determining carbon monoxide. The can is cylindrical in shape with a pet cock on each end. It is first filled with water then emptied in the contaminated area and the pet cocks closed. Contaminated air then replaces the water. The sample is then titrated in the laboratory with iodine pentoxide and sturch indicator. If you don't have facilities to do this, your local gas company will probably do it for you.

Tanks of known concentrations of carbon monoxide are also available. Samplers can be standardized or checked against this.

WATCHING T&RI PROGRESS

We are extremely interested in the details on the courses presented by the AFS-Training & Research Institute courses. You are accomplishing some very useful work. An organization of this kind demands a great deal of time, both from the organizers and from those who follow the courses. It is certain that this time is very well employed. We will continue to follow the development of this organization.

G. BLANC
Centre Technique Des Industries
De La Fonderie
Paris, France

WANTS T&RI DETAILS

We would appreciate information on the sponsorship of T&RI courses. Specifically on costs, courses available, and enrollment required.

NICK SHEPTAK
Secretary
AFS Saginaw Valley Chapter

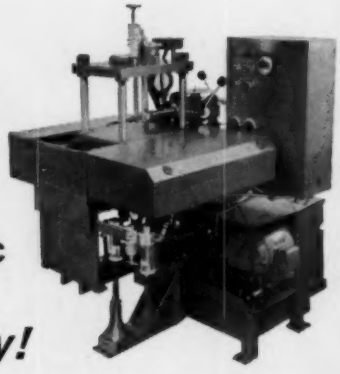
Editor's Note: The information is being forwarded. Chapters are advised that the T&RI schedule for 1962 is now being established. Requests should be made early for inclusion in the over-all plans.

(Continued on page 26)

Produce Larger Wax Patterns

. . . on a Semi-Automatic Basis . . .

Economically!



Sherwood Wax Injection Press with die closing mechanism has positive self-locking action! Wax for Investment Casting Patterns is injected at lower temperature — under direct hydraulic pressure! Your patterns are more accurate — no matter how intricate the shape.

Sherwood Press Model WP-60 has two cylinders of increased capacity — 285 cu. in. each. We offer this press complete with mechanical die-closing press attached opposite horizontal nozzle. Press platens 16" wide by 12" deep with 12¼" clearance between vertical columns, accommodate dies up to 12" square by 6" high. Included are: vertical spring loaded nozzle, reserve cylinder tank, 2 extra wax cylinders, and 1½ hp., 220/440 volt, 60 cycle, 3 phase AC motor.

Price, F.O.B. Kenilworth, N. J. — $5525 Complete!
Sherwood Wax Injection Press Basic Models start at $1495!

Write Today For Bulletin WP60 giving full details!

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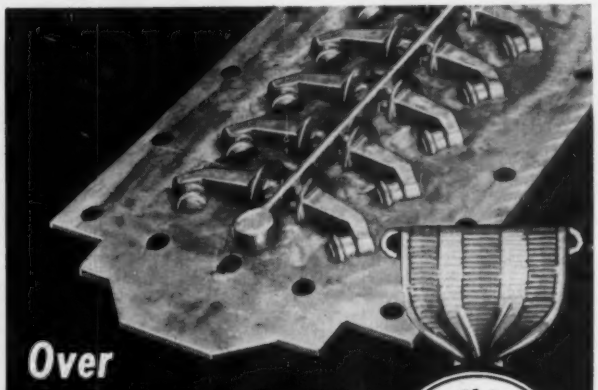

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Circle No. 136, Pages 143-144

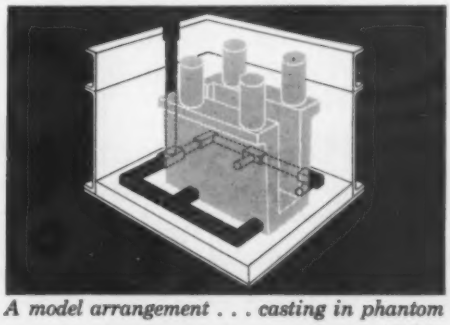
REFRACTORY GATE AND RUNNER TILE

AVAILABLE IN ROUND OR SQUARE SHAPES

Harbison-Walker Gate and Runner Tile are strong and withstand rapid metal flow without excessive erosion, assuring cleaner castings. Tile of minimum diameters may be used, with considerable reduction of metal in the gates, and consequent savings in scrap loss. Being much stronger than sand, the refractory tile permit pouring under high pressure, thereby reducing gas inclusions. • Installation in the mold is easier and faster, and overall cost is less. And the excellent workmanship of H-W Gate and Runner Tile accounts for their good tight fit. • More than 200 sizes and shapes are available, including cups or funnels, round and square tile with plain or jointed ends, crosses, tees and ells for complete gating systems. Many of the more popular sizes are available from stock. Write for catalog. • Harbison-Walker supplies refractories for other pouring equipment, including sleeves, nozzles and monolithic linings for foundry ladles.

Shapes for every need

Tight-fitting joints



A model arrangement . . . casting in phantom

HW 61-20

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World's Most Complete Refractories Service

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"This year," says Chief, "you must take care,
With costs, the way they mount,
And wampum now so hard to get—
It's what you save that counts!"

When you think of SILICON . . . think of KEMCO!

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The superior form of silicon introduction . . . available in 60 and 30 lb. pigs and 12½ lb. piglets . . . In regular analysis or alloyed with other elements. For uniform high purity, aluminum producers specify Kemco Silicon Metal.

Circle No. 138, Pages 143-144

(Continued from page 24)

METAL MOLD REACTIONS

"Factors Affecting Metal-Mold Reactions," by G. A. Colligan, L. H. Van Vlack, and R. A. Flinn, appearing in the January MODERN CASTINGS, contributes substantially to the knowledge of the subject.

In a general way, we agree with the conclusions and many of the comments made by the authors. On the other hand, there are a number of questions regarding the manner in which some of the conclusions are reached. There are repeated references to the effect or the role of the so-called "oxidizing" or "reducing" conditions. These terms have been used in connection with mold reactions by nearly any one who has worked with the subject. In many cases, they have probably been used incorrectly. The authors seem to recognize this, but still leave an element of doubt in use of terms such as "more oxidizing" or "less reducing," etc.

There is reference to "oxidizing conditions" in a green sand mold and to the "strongly reducing conditions" in a shell mold. The equilibrium diagram, shown in Fig. 1, seems to suggest that the interface reaction at high temperature would not proceed unless the percentage of CO_2 were above a value somewhat more than 3 per cent. Attention is drawn to a statement on page 109 pertinent to the oxidizing conditions prevailing at 3.9 per cent CO_2. This is further illustrated in Fig. 14, illustrating mold wall attack. Thus, there is question at what stage does the atmosphere become reducing. A statement on page 109 allows that "under reducing conditions, a sample of the same size exhibited no reaction." It might be useful to have these reducing conditions described. This takes on added significance in view of the comment to the effect that "the oxidizing nature of the green sand mold produces extreme interface reaction . . . The reducing nature of the shell sand mold permitted little interface reaction." In other words, it is stated that the shell mold produces a reducing atmosphere, and yet is not immune to the penetration effect.

This question of oxidation might be further explored, either in light of comments that are made or by examination of the photomicrographs. Attention is called to the presence of higher oxides of iron

(Continued on page 28)

HOLD 'EM DOWN!

MOLDING COSTS

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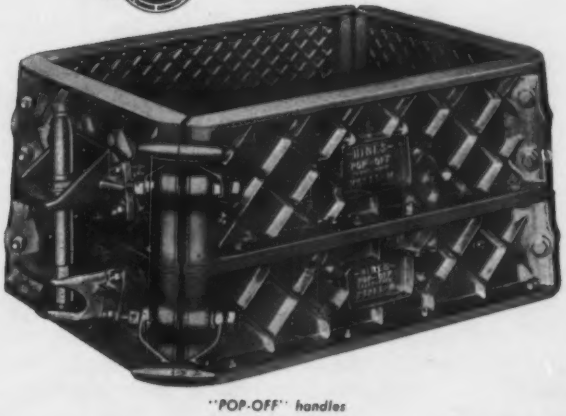

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Circle No. 148, Pages 143-144

(Continued from page 26)

that occurred in green sand molds. On the other hand, the micrographs of shell molds show no oxides, but rather point out that iron is present as a result of the reducing conditions.

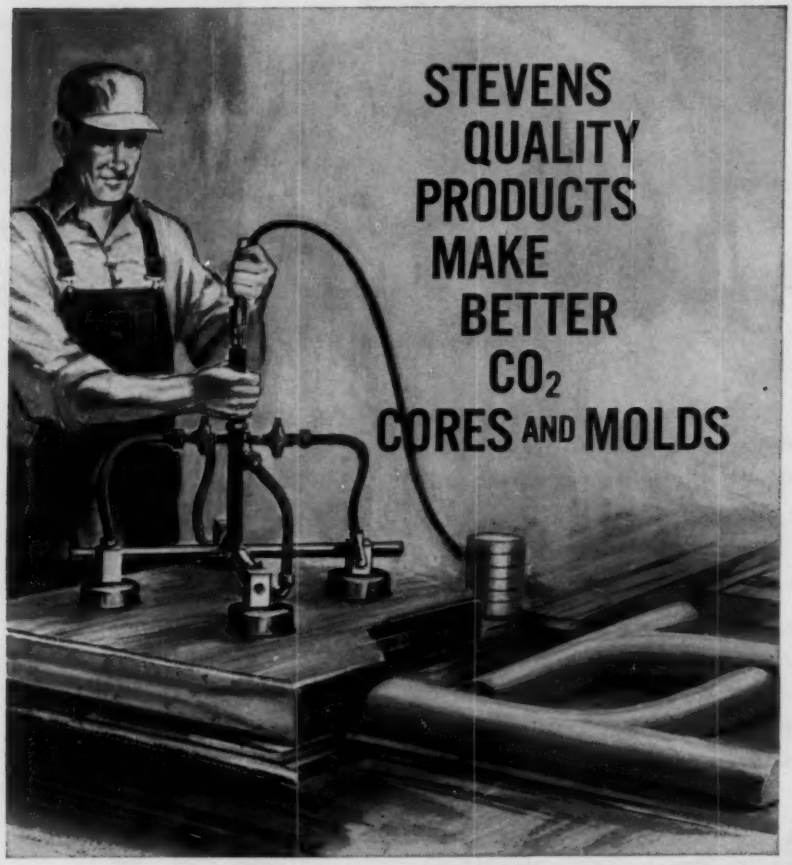
It has been pointed out that even small additions of manganese greatly lower the reducing tendencies of a given gas mixture. This apparently makes it impossible to prevent the formation of a liquid silicate melt in the presence of manganese. While the authors have not claimed the elimination of penetration with a shell mold, it is of some interest to note that even with the highest manganese addition, the amount of reaction at the interface was less than occurred in green sand with the smallest manganese addition. Would it be unreasonable to have expected progressively increasing penetration with higher manganese in the shell mold, since this is the case with green sand?

It would be of some interest to know by what technique the authors obtained the analysis of gas at the interface. It seems that this may be a matter of great importance, yet the method of sampling at the correct location and at the proper time would seem to present a difficult situation.

In the discussion of the casting results, a comparison has been made of both green and shell sands with increasing amounts of manganese in the steel. In discussing the microscopic evalaution of the interface reactions, it is stated there is "extensive evidence" of the formation of a liquid silicate melt. Similarly there is a statement relative to the small amount of silicate occurring in the shell mold. Is quantitative estimation possible on the basis of microscopic examination? The photomicrographs themselves would not permit such a conclusion. We assume that such a quantitative evaluation would not be obtainable from the particular illustrations contained in the report. Was this opinion derived from a more extensive examination of specimens on the microscope, or was it influenced by the amount of reaction products adhering to the castings and evident on a macro-examination?

In at least two places, the authors point out that the possibility of preventing interface reactions by the use of neutral or reducing gases is most impractical. We are inclined to agree that this is entirely true, but it is questionable whether the statement follows from the information that has been presented. For instance, it is stated that "observation of the phases present . . . indicates that normal cast metal practice operations lie above the boundaries between the liquid silicate melt field and the solid and liquid iron field." This statement is followed by another statement that the possibilities of using neutral gases, therefore, are impractical. Would it not be well to expand on the basis for this conclusion? It is our opinion that the use of such gases would merely serve to displace air that would exist in the mold cavity prior to pouring. Such gases would be displaced by the metal during the pouring operation. The liquid metal then coming in contact with the mold wall would be subjected to whatever gas reactions or atmosphere were generated at the mold interface by reactions taking place in the sand itself. The possibilities of controlling mold interface reactions by the use of organic materials thus are not apparent simply on the basis of

(Continued on page 30)



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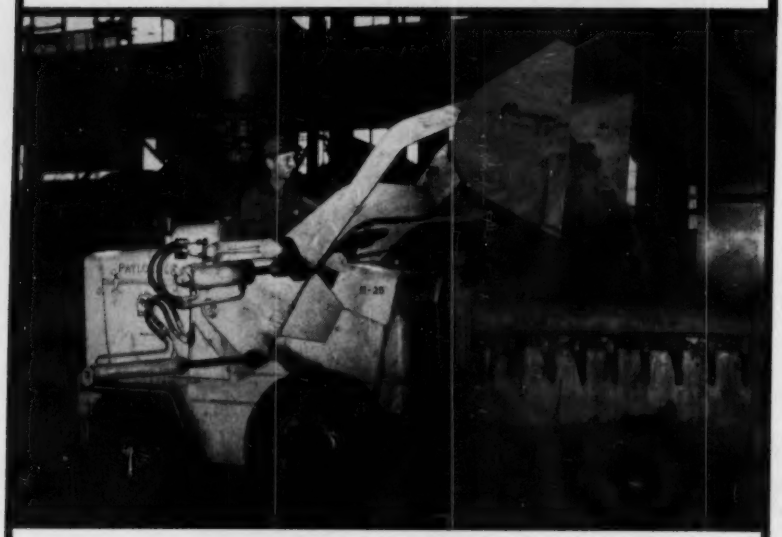

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Circle No. 142, Pages 143-144

(Continued from page 28)

recognizing that normal cast metal practices produce penetration.

P. J. NEFF
Assistant Manager
Manufacturing Research Laboratories
American Steel Foundries
East Chicago, Ind.

RELIABILITY OF LEAD TEST

We would like any information you have as to the reliability of basing lead intoxication cases on the basis of urine tests. Should a man be removed from exposure if the result of his urine analysis indicates a lead level of 0.180 mg per liter or more. How reliable is a stipple cell count?

C. W. S.

Editor's Note: Stipple cell counts and lead excretion rates are not of themselves of any value unless coupled with clinical signs and symptoms. Therefore they should be used as aids only in diagnosis.

When a man has symptoms similar to those of lead poisoning but the atmospheric concentration is low and the spot urine sample shows a lead concentration of only 0.180 mg/liter, then the physician should look for other causes of the symptom.

The presence of stipple cells in the blood is non-specific for lead poisoning. Other causes can also account for their presence. They therefore have negative value. In other words, if they are not present, a diagnosis of lead poisoning is faulty. If they are present, lead poisoning may or may not exist. Even when blood-lead and urinary-lead levels are high, you can only conclude that there has been excessive absorption of lead—not necessarily intoxication.

SEEK ALLOY DATA

The Alloying Committee (12-H) of the AFS Ductile Iron Division will compile information on the effects of alloys both beneficial and detrimental on the properties of ductile iron. It is urged that any available information be sent to Committee Chairman D. L. Crews, Research Associate, James B. Clow & Sons, Inc., Coshocton, Ohio or to myself.

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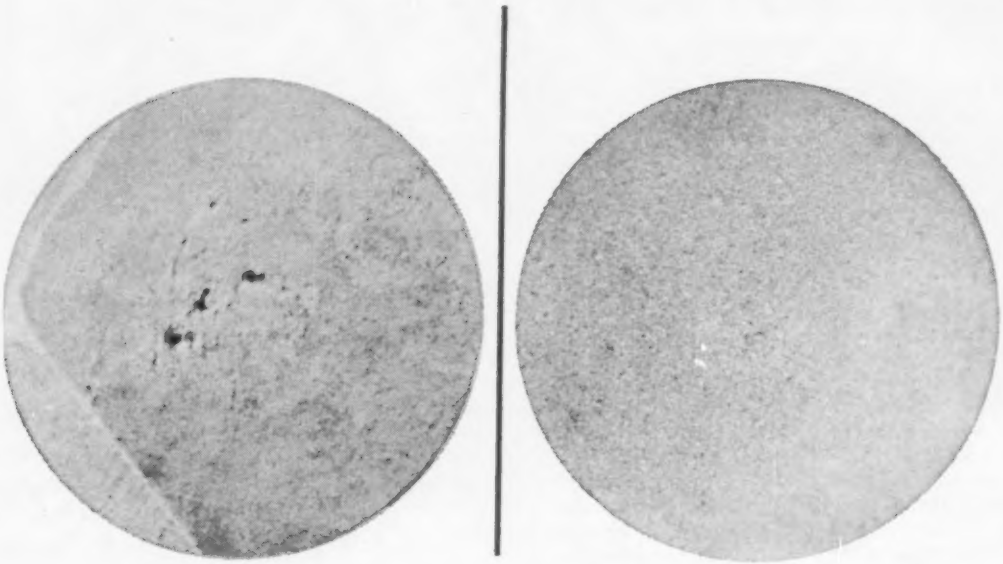

Sand casting at left shows typical surface shrinkage. Sand casting at right, produced under same casting conditions, was made from Federated PT Grade ingot.

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Circle No. 143, Pages 143-144

Management for Creativity

By R. E. BETTERLEY

It is gratifying to notice a growing resurgence of the basic attitudes which were largely responsible for the economic and industrial development of the United States. I am speaking of the energetic, forceful and *creative initiative* shown at all levels of our society. Industry, today, is recognizing the value and potential of personnel creativity. Increased patents, cost-reduction programs and effective suggestive systems are typical objectives sought and achieved.

Management is more aware of the importance of employee ingenuity. Yet, in the struggle to have personnel productivity keep pace with spiraling wage structures and improved physical equipment, management too often overlooks the *basics* which could achieve its goals. The creativity and imagination of employees is sought on one hand and lost on the other because of improper methods, conditions or employee relations.

I am not advocating that foundries, regardless of size, hire a training director and set up formal programs to teach "creative thinking," "creative engineering" or "imagineering." I do, however, propose that management should—by every feasible way—*create the proper climate* for fostering ideas and employee growth.

To accomplish creativity and improvement in others, the importance of self-development must be appreciated. We don't and cannot change people! They must change themselves. We can, at the best, change conditions, providing opportunities for creativity and growth.

Through a better understanding of people, management can accomplish big gains in developing creativeness. Suppose we return to fundamentals. People are *not* machines or "things" to be lined up like dominoes for a pre-determined performance. They are personalities—individuals — human beings — all having peculiarities.

Cloyd S. Steinmetz, director of sales training, Reynolds Metals Co., wrote in the Journal of American Society of Training Directors (August 1961): "In fact, people are queer, as indicated by the story of the Quaker who said to his wife, 'Miranda, all people are queer except thou and me, and sometimes I think thou art queer also!'—And he came within one of being 100% right."

Many foundries do encourage personal freedom of expression and development. However, may I suggest they also consider the following:

Use Problem-Solving Groups — Supervisory and management personnel can be brought together to solve specific problems.

Encourage Two-Way Plant Communications—This invites creativity at all levels of personnel. Creativity, then, *improves* communications because of need.

Permit Key Personnel to Put Their Ideas into Practice — R. B. Parker, of American Brake Shoe Co., clearly emphasized this point when speaking on Management Development at the 1958 AFS Convention. Speaking on the "freedom" of potential executives, he said, "Most of all, it means what we call 'freedom to fail.' Unless a man is free to go ahead with *his* ideas, despite the risk of their failing, you cannot really be sure of his potential as an executive."

Permit Employees the Right to Challenge Policy — Key personnel should be free to know the "why" of policy. They should be able to state beliefs and cite obstacles to trial performance.

Rotate Qualified Personnel—This can be used effectively to broaden the employee's experience and prevent extensive specialization.

Hear the Employee Out — Management and supervisory personnel should improve their "listening" habits. This can be a sore point in human relations.

Apply the Golden Rule — This, above all, is of utmost importance in *all* employee relations.

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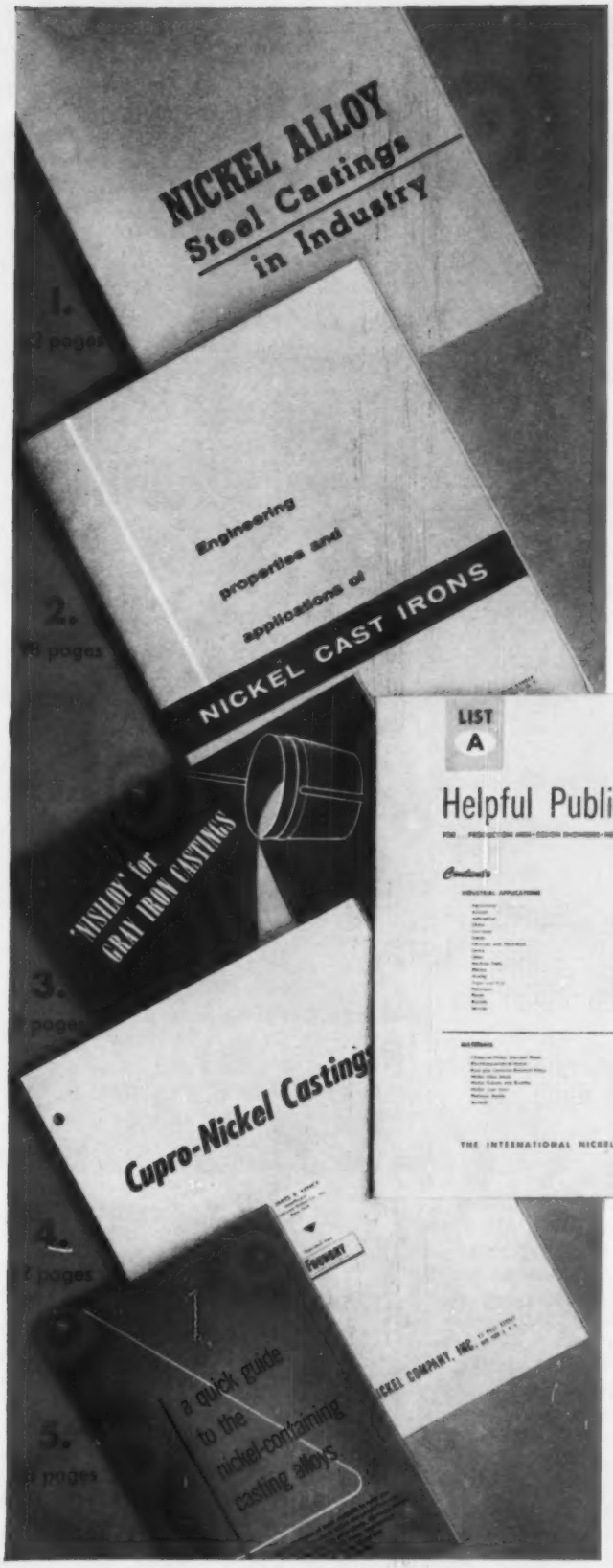

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Techniques for Metal Analysis

Methods for Chemical Analysis of Metals . . . American Society for Testing Materials. 722 pages. Latest in series providing a source of analysis methods supplemented by new testing procedures perfected and approved by committee. Among topics covered are: sampling methods, chemical analysis of ferrous and non-ferrous metals, and spectrochemical and microchemical analysis methods. Also data on standard samples of metals issued by National Bureau of Standards. Includes various methods in previous editions which have been brought up to date, new methods taking advantage of shorter or more precise procedures which have been developed, and methods for additional metals.

Thermophysical Property Study

Handbook of Thermophysical Properties of Solid Materials . . . Alexander Goldsmith, Thomas E. Waterman, and Harry J. Hirschhorn. Five volumes. Published under contract with U. S. Air Force. The 5-volume work of reference was compiled and prepared by Armour Research Foundation for use of government contractors in the missile, aircraft, and nuclear science fields. Published data on 12 vitally important physical properties are conveniently arranged. Five properties, density, melting point, latent-heat of fusion, latent heat of vaporization, latent-heat of sublimation are grouped together on a single data sheet. The other seven properties, specific heat, thermal conductivity, thermal diffusivity, emissivity-reflectivity, linear thermal expansion,

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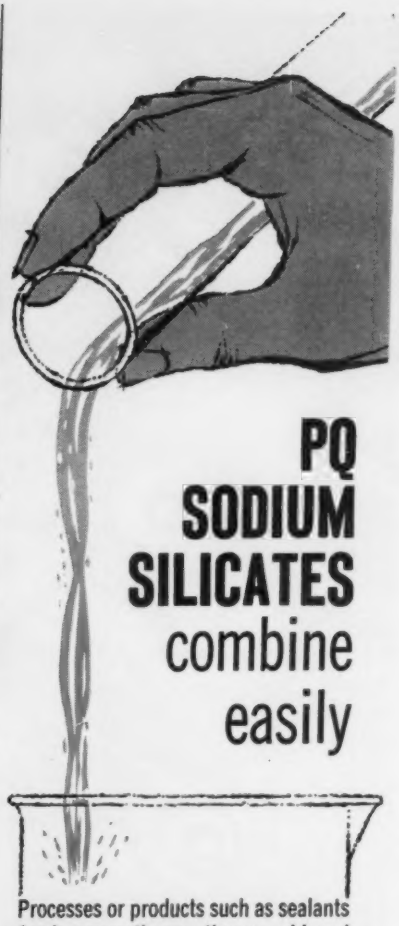

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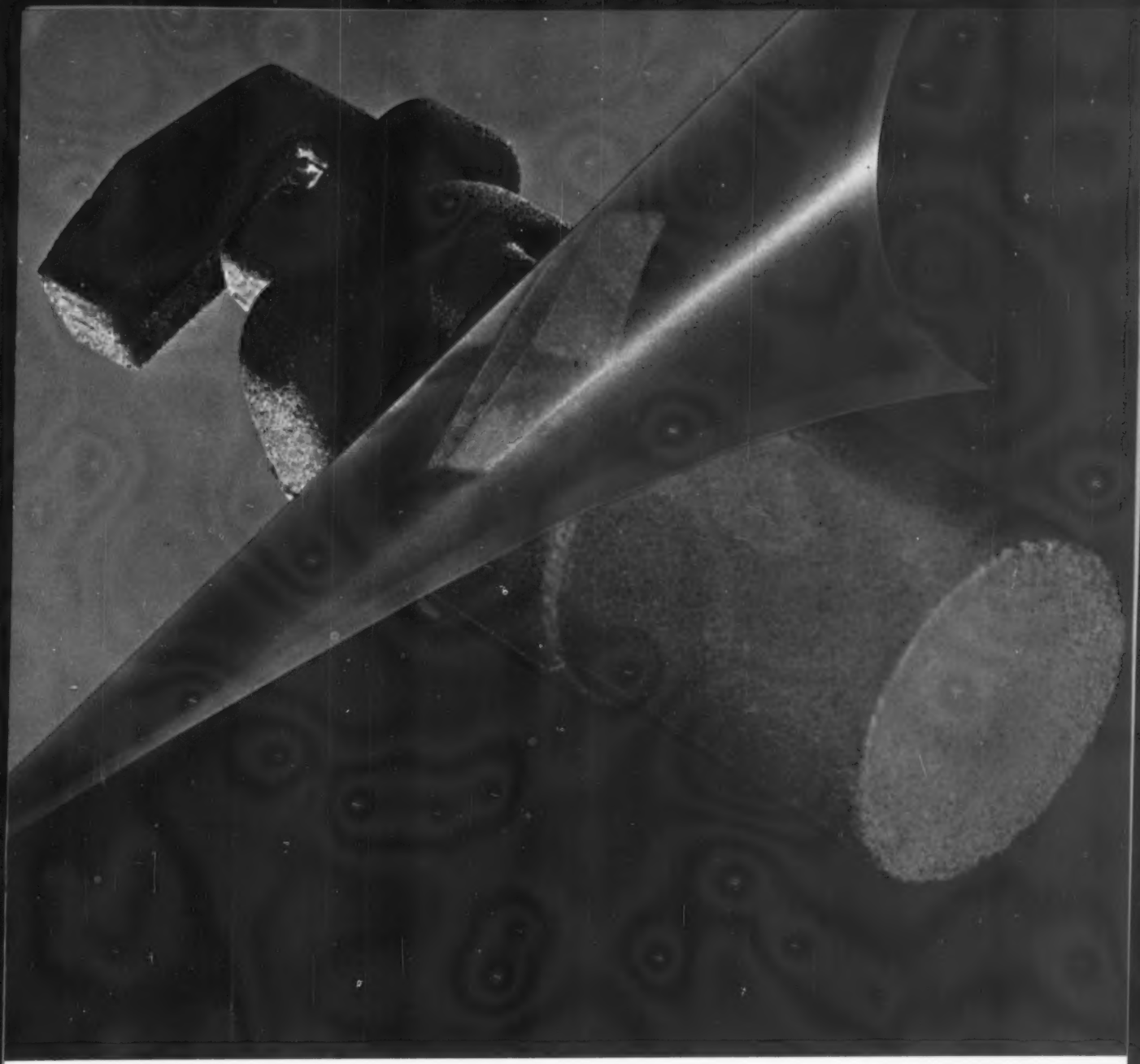

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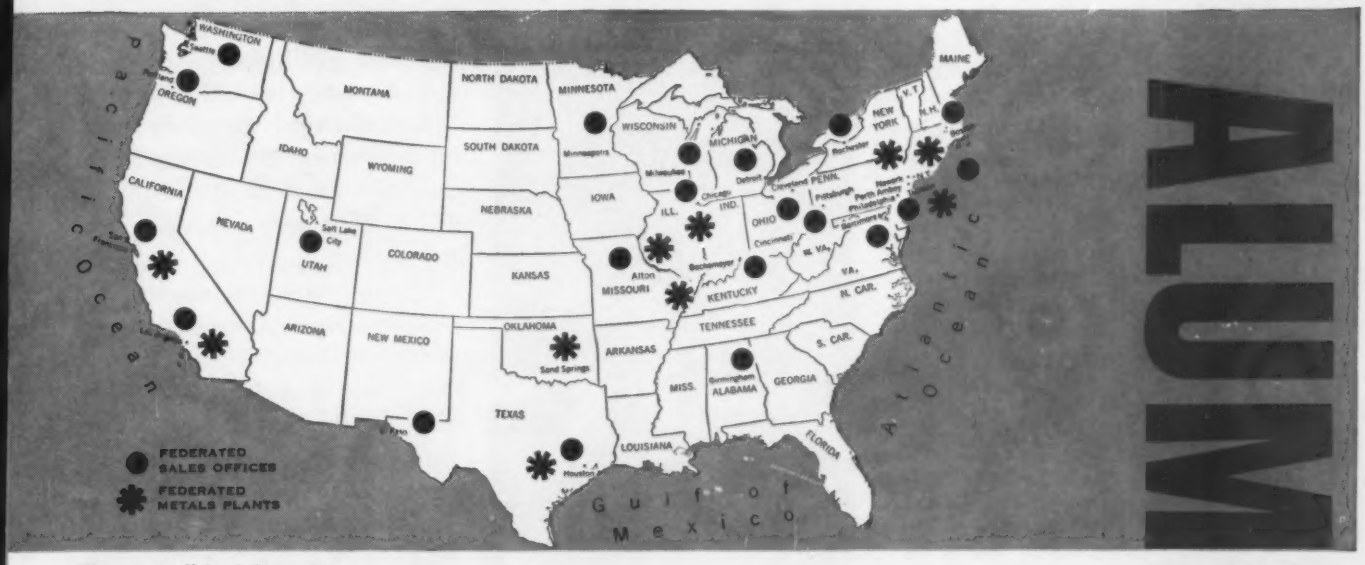

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Circle No. 151, Pages 143-144

(Continued from page 36)

vapor pressure, and electric resistivity, are evaluated on separate data sheets and plotted on separate graphs as functions of the temperature.

The investigator's method of testing is given for each entry; special additional information includes the experimenter's own estimate of the accuracy of a test, prior treatment of the material or special environment of the test. The source of each plotted point or numerical value is identified in the list of references in the final volume. Materials are elements melting above 1000 F; alloys; ceramics; cermets, inter-metallics, polymeric materials, and composite materials. The final volume is a reference guide, listing sources of every item of data. Authors are listed alphabetically and author and subject indices are cross-referenced.

Indian Foundry Molding Sands

Foundry Moulding Sands of India . . . Jatinder Mohan, R. M. Krishnan, B. R. Nijhawan, P. K. Gupte, and B. V. Somayajulu. 180 pages. A survey and research on Indian foundry sand and molding materials undertaken by the National Metallurgical Laboratory, Jamshedpur. Greater emphasis on quality brought about this previously partially explored area. The monograph shows the result of 42 samples of molding sands from various sections. Twenty constituted natural sands, 11 crude silica sands, 10 high silica sands, and one a special zircon sand. In addition, four samples of bentonite sands were examined for use as bonding materials.

Finding Metallurgical Data

Guide to Metallurgical Information . . . Elizabeth W. Tapia. 96 pages. A world-wide compilation of where to find metallurgical information. Coverage includes not only all types of published literature but also agencies and other sources of important metallurgical information including societies, trade associations, research institutes, government agencies and technical services concerned with metallurgy as well as books, peri-

To a foundryman who wants to stay COMPETITIVE:

CUT HANDLING IN HALF or better. Shell molds and cores are light to lift, easy to handle. No hoist is needed even for a core this big.

We'd like to help you.

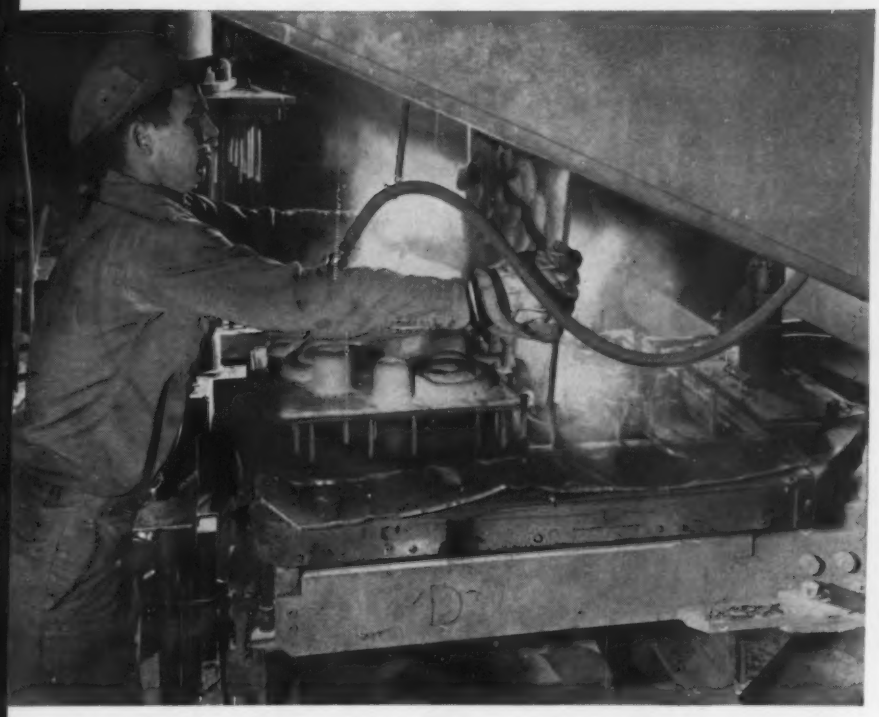
You've spotted the trend. You've observed that customers are getting more demanding. That quality standards are heading higher. That competition is growing tougher.

You're aware that service, always important, is becoming more important than ever.

And you've decided that these facts spell opportunity—for the foundry that can adapt to them and make the most of them.

Shell molds and shell cores fit into this growth picture. We'd like to help you make the most of the business opportunities inherent in the shell process. There's a complete line of Durez® foundry resins to give you the results you want—consistently.

Just as important, there's a Durez man nearby who can help you use these resins to best advantage in your foundry. He talks your language. He wants to see you grow. Why not drop us a line today, and we'll have him pay you a visit.



STREAMLINE PRODUCTION of molds and cores. Modern shell-molding machines can produce a high-quality mold every 30 seconds. Shell cores let you get rid of wires, forget about core driers; save you a long baking cycle. Good collapsibility cuts shake-out time on intricate castings.

SAVE ON STORAGE SPACE—yet have plenty of molds and cores ready for rush orders. They're simple to store and there's very little risk of breakage. How much space could *you* save by stacking big cores like this?

DO LESS MACHINING (perhaps none at all) on castings that must meet close-tolerance specs. Get smooth bores in valves, engine blocks, pump parts—without grinding. Reduce the customer's machining cost by producing smooth, sand-free surfaces that machine faster, let tools last longer.

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HOOKER CHEMICALS PLASTICS

Circle No. 152, Pages 143-144

odicals, microforms, theses and translation. Contains three indexes, author and agency, book and journal title, and subject.

Continuous Casting of Steel

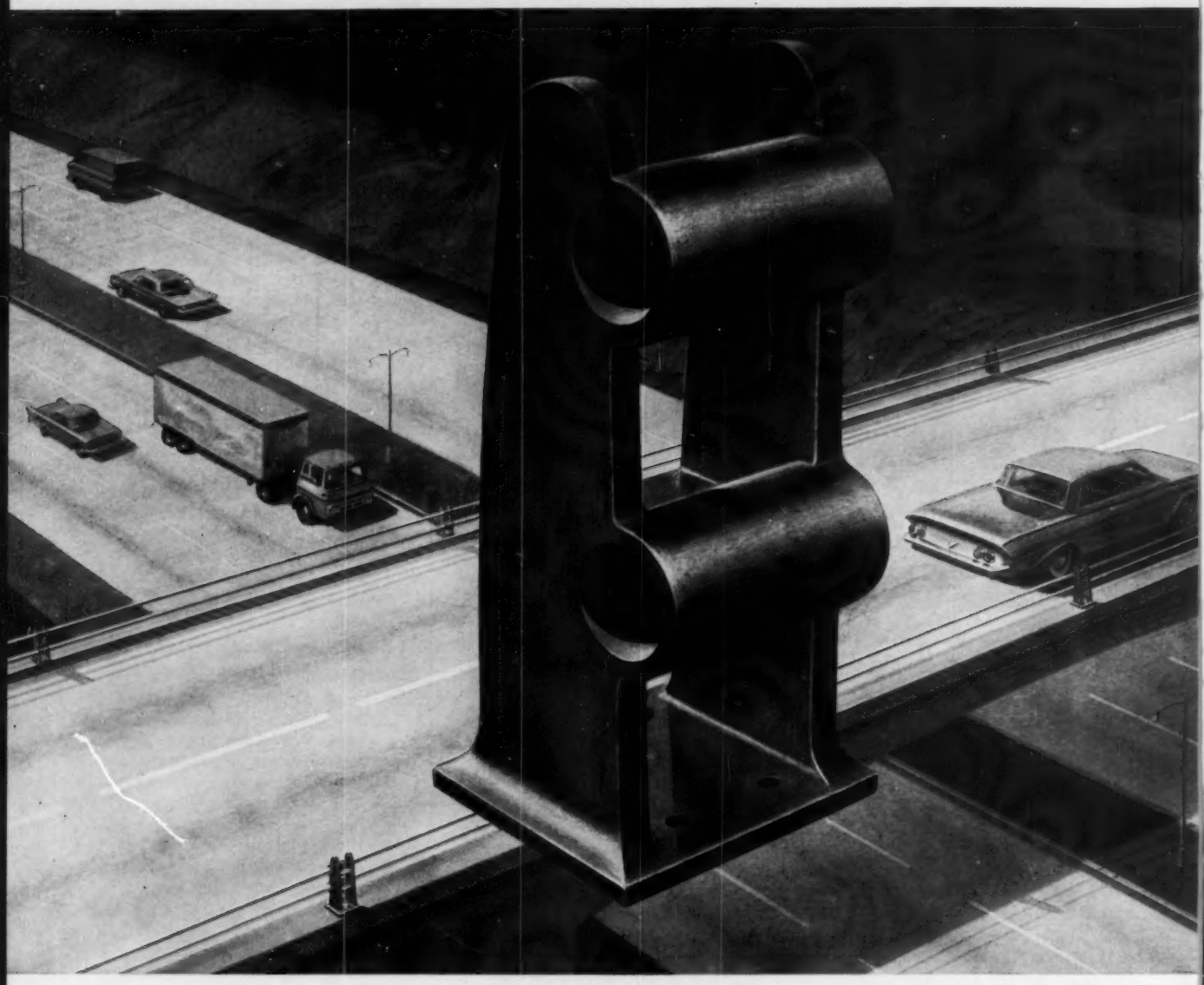
Continuous Casting of Steel . . . M. C. Boichenko. Translated from Russian. 124 pages. A short survey of the present position of semi-continuous and continuous casting of ferrous and non-ferrous metals and alloys. A critical survey of the development of the present methods of the continuous casting of steel, both abroad and in the U.S.S.R., is given and some technical details regarding equipment are considered. The technological parameters of continuous casting of steel are indicated and the comparative investigations of the quality of cast ingots produced by continuous casting and by the normal method of casting into ingot molds are given. Intended for metallurgists and may be used by advanced students.

Techniques of Management

Management by Results, The Dynamics of Profitable Management . . . Edward C. Schleh, 251 pages plus index. Presents a philosophy of management on which those in top management or in supervisory positions can build a more dynamic operation while attaining the fulfillment of individual needs.

It presents basic management, organization, and administrative principles to implement this philosophy at each level. It demonstrates how the application of management philosophy brings out the latent talent and abilities in all management personnel. Chapters deal with the challenge of management; delegation by results; the basic management design — management objectives; the dynamics of management objectives; developing the freedom to act; policies that stimulate individual initiative; special characteristics of groups; managing from the second management echelon; encouraging supervisory decision-making; the complexity of supervising variable positions; encouraging uniform results from variable positions; maintaining individual accomplishment from variable groups; the question of "when is staff profitable?"; minimizing staff-line opposition; expansion into multiple organization; stimulating cooperation in complex organizations and future of management.

How the Foundry Industry Serves America . . . #13 of a Series



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This is just another example of how modern iron castings offer you superior benefits at substantial savings.

For the production of structurally sound iron castings, Hanna Furnace provides foundries with all regular grades of pig iron . . . foundry, malleable, Bessemer, intermediate low phosphorous, as well as HANNA-TITE® and Hanna Silvery.

Facts from the files of Malleable Founders Society

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Circle No. 153, Pages 143-144

In the interest of the American foundry industry, this ad (see opposite page) will also appear in

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They All Had Their Ace in the Hole

BY HERBERT J. WEBER

Prior to the enactment of workmen's compensation laws in the United States, an employee's legal remedy for an industrial injury was governed by the common law.

The employer had these three common law defenses:

1. Assumption of risk. The employee knowing a job to be hazardous, assumed the risk of injury and therefore lost his right to compensation.
2. Acts of a fellow servant. If an employee were injured because of the carelessness of another, the injured had a claim against his fellow worker but not against the employer.
3. Contributory negligence. In order to obtain redress, the employee had to prove contributory negligence on the part of the employer. If an employer knew that a catwalk, for example, was in dangerous condition and failed to repair it, he was negligent.

Thus, you see the employers all had their ace in the hole. The worker had slight chance of beating a pat hand like that.

Even if the worker won, he had no assurance of collecting damages from a company financially unable to pay.

On the other hand, the employer was faced with the possibility of unpredictable judgments and outrageous awards such as we see granted today under the common law in automobile accidents.

Thus workmen's compensation laws were enacted as a compromise between the extremes of abuse of justice; and justice rarely smiled on the injured man.

In the beginning, the laws covered accidental injuries only, but later they were extended to include occupational diseases. Now they include exaggerations.

We also have compensations for phony back injuries and off-the-job back injuries.

The phony injury is one of the toughest for a conscientious physician to detect and the malingerers find this field to be a lucrative source of tax-free income.

Then there is the true back injury that happened on the way to work. What seer or Delphian oracle can divine that it did not occur on the job.

Thus today we find the employees have their ace in the hole, too.

The basic philosophy behind the laws was to *guarantee* to the worker a *portion* of the wage loss and medical expenses caused by accidental injury or occupational disease.

However, today we find compensation granted for loss of hearing even though there is no loss of earning capacity.

In noisy occupations the very noise that causes hearing impairment is usually so intense that speech communication is impossible and so the impairment seldom results in inability to stay on the job or inability to earn full wages.

Today, because employees have their ace in the hole, employers have little chance of beating their pat hand.

But, here's a pretty good hand that may beat that ace in the hole.

1. Have more thorough preplacement physical examinations including spinal x-ray. Some person's spinal make-up predisposes them to back injuries.
2. Re-examine all work stations. If a southpaw has to work on right handed levers or if men must work in crowded spaces you're asking for back trouble.
3. Just as you periodically audit your books so also audit your safety program. What's wrong?
4. Give notable recognition in one or other form to employees with outstanding safety records. Their record then becomes contagious.
5. Don't settle claims too readily. Once you're known as a soft touch, word gets around.

Even then you're apt to lose but not as often because you'll have an ace in the hole too.

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*Controlled
Cupola
Charge
THE OPEN DOOR TO
GREATER FOUNDRY PROFITS CCC*
By using— Interlake's famous Meltrite pig iron + steel + your own returns, you are sure of a known analysis in the charge.
The results: (1) Shippable castings at lower cost.
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Remember—Meltrite is always in dependable supply.
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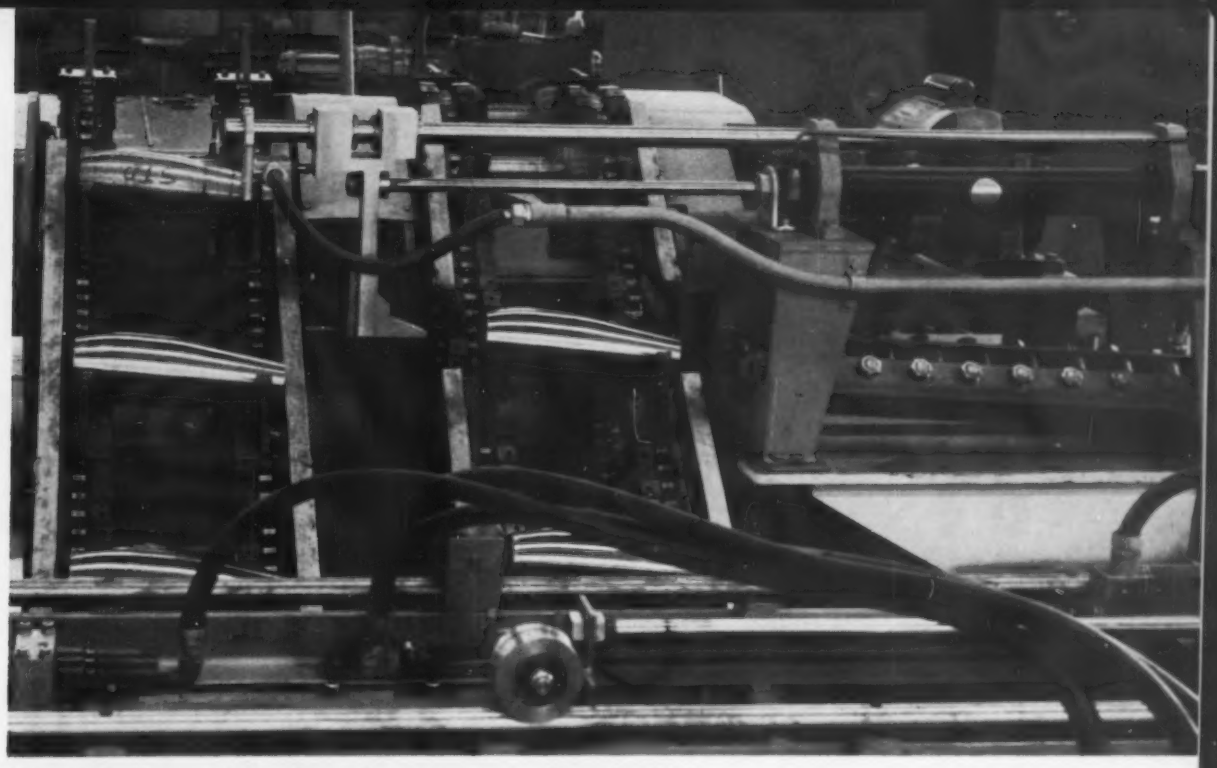


Mortar shells, as pictured on the cover, pass through rigid ultrasonic inspection at Albion Malleable Iron Company to meet the demands of Army Ordnance.

MARKET OPPORTUNITIES

For the metalcaster seeking new markets, ordnance is an eager prospect. New weaponry coupled with modern foundry technology present a challenge to American metalcasters' ingenuity.

Ordnance — Unlimited Potential for Castings

By JACK H. SCHAUM

THE ORDNANCE MARKET is one that draws on virtually all types and kinds of metalcasting production. It is a demanding market, but one that holds sales potential and market opportunities for any foundrymen who want to go after it.

For many years castings have been used in a myriad of ordnance material. Ordnance castings range in weight from only a few ounces to some that tip the scale at more than 24,000 lbs. Ordnance uses bronze, aluminum and magnesium alloys, steel, cast iron, malleable iron and ductile iron castings as well as some of the new rare metals and alloys (MODERN CASTINGS, October 1961, page 41).

Strength levels range from class 20 cast iron to a 150,000 psi tensile strength in steel and 40,000 psi in aluminum.

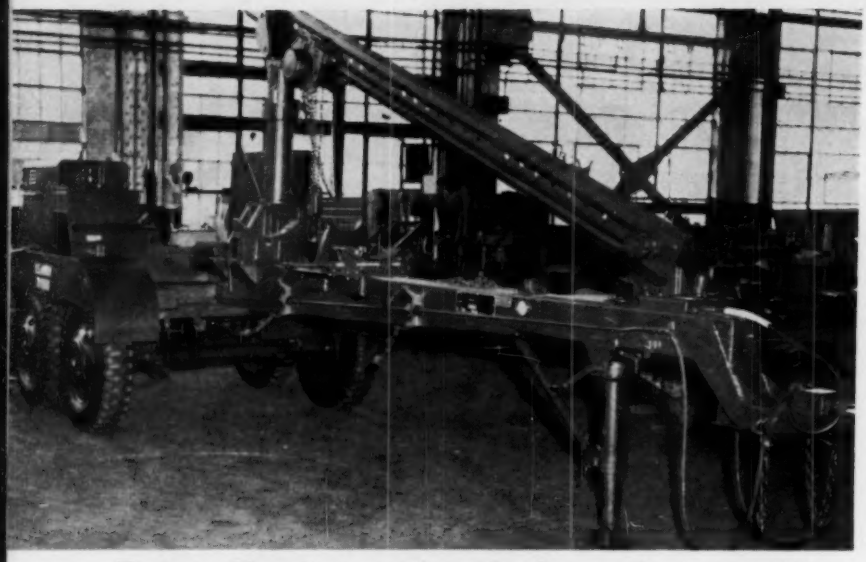
Quality demands vary from a low strength commercial casting to those requiring class 1 radiographic quality. In addition, magnaflux and hydrostatic quality castings are sometimes specified.

Military requirements are always exacting—perhaps more so than many industries supplied by metalcasters. Yet castings play a major role in the production of ordnance equipment.

How to Sell Ordnance

What are the selling points metalcasters have to offer? According to one government spokesman, the fact that casting is a process which lends itself to production of only a few parts or many parts to a desired configuration is a big point. This, he says, is important in ordnance contracts.

Major General W. K. Ghormley, army chief of ordnance, says that castings are of military



There are 72 castings, mostly steel with some aluminum and brass, on this Honest John Missile weapon trailer.

What Is Ordnance?

A high-ranking Army officer gave us this definition: Militarily, the term "ordnance" includes not only weapons of every type, manually and electrically operated, but all parts, mountings—including wheeled or tracked vehicles—ammunition, and machinery for repair or servicing weapons or their supporting appurtenances.

importance because they can be made in intricate designs and offer economic incentives over competitive methods of fabricating parts.

There is no current major weapons system that does not require castings, said the general, and there is no projected system that would not be improved if the potential of castings could be more fully exploited.

The cost factor is an important one. Particularly in low volume work, casting is the only way for rapid procurement of prototypes. Frequently, when a cast prototype is successful, the production run is contracted to a foundry.

Five of the castings used in the Honest John trailer. Four of these are steel at the 35,000 psi yield strength level. The fifth (gear) is a bronze casting.

Ordnance Critics

The metalcasting industry comes in for some severe criticism, too. One ordnance expert believes that four problems—certainly not new or confined to the ordnance market—seriously hamper more widespread use of castings. The four:

- Inferior casting quality
- Inconsistency of quality
- Failure to deliver on schedule
- Cost

An arsenal expert questions, "Are U. S. troops to be denied the benefits of superior ammunition because metalcasters do not have the necessary technical skill?"

Other ordnance authorities believe that metalcasters haven't spent nearly enough effort in research and development. They want improved mechanical properties for light metals, increased reliability and more exact dimensions of finished castings.

Increase in Usage

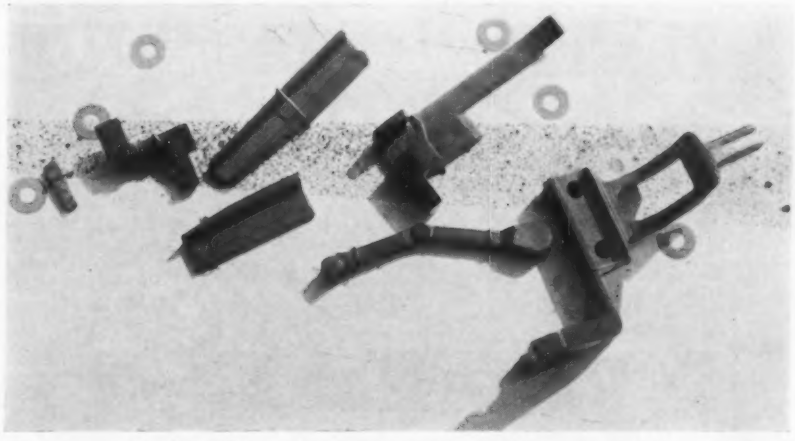
Plainly, the castings industry has made vast progress in selling ordnance in recent years. It is perhaps paradoxical that the greatest growth has come since the end of World War II.

For example, the ultrasonic detector has cleared the way for better quality control. Using the principle of sonar waves through water, the detector automatically rejects any unsound castings it views.

Ultrasonic rays are directed at the casting so that they rebound inside the casting until lost. If a casting is defective, the sound is deflected through the machine and the casting is rejected.

Three steel castings on an M-60 tank gun. The breech ring is special analysis steel heat treated to produce 130-160,000 psi yield.

This is a thin walled, nodular (ductile) iron instrumentation nose cone used in research and development of the Redstone Missile.



These are shell mold and investment castings used in the feeder housing assembly of the "Vulcan" 20mm, six-barreled cannon. This weapon uses many other castings as well.

Small, precision steel castings used on the M-85 machine gun. This gun is on an XM-21 tank.

The inspection process takes just nine seconds.

The result of this inspection is an 81 mm mortar shell termed by General Ghormley, "superior to anything used in the field."

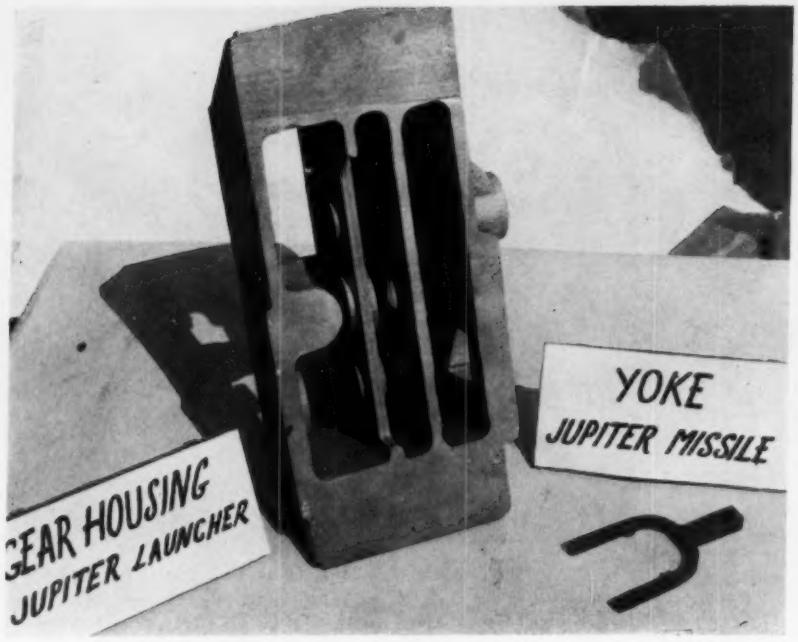
Development of this 81 mm pearlitic malleable shell body is significant and opens a huge new market for metalcasters. From sales of about 27,500 tons per year 15 years ago, shipments of these shell bodies rose to 190,000 tons last year.

But the metalcaster who wants some of the ordnance business had better know something about ordnance and weapons or be prepared to learn quickly.

For example: in perfecting the 81 mm shell, the metalcaster had to be concerned with ballistics. The proper trajectory of a fired shell depends almost entirely on its balance and weight distribution. Consequently, much of the development work was concerned with obtaining perfectly uniform wall thickness within a few thousandths of an inch. Another allied problem was precise metallurgical structure: unvarying from one days' melt to the next.

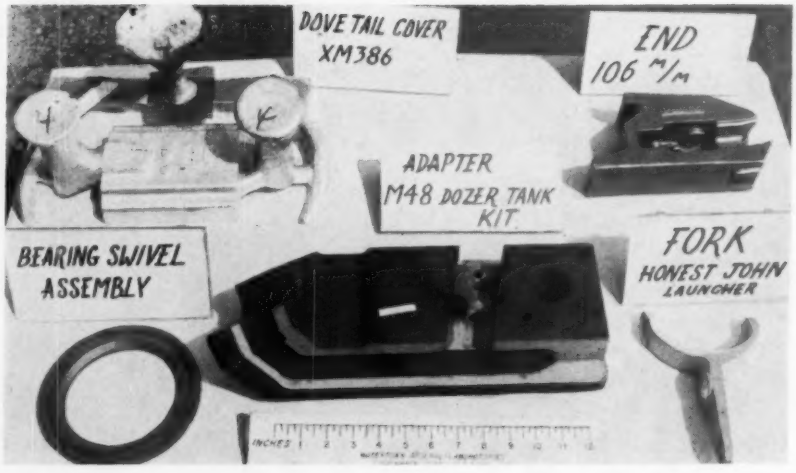
Cooperation Needed

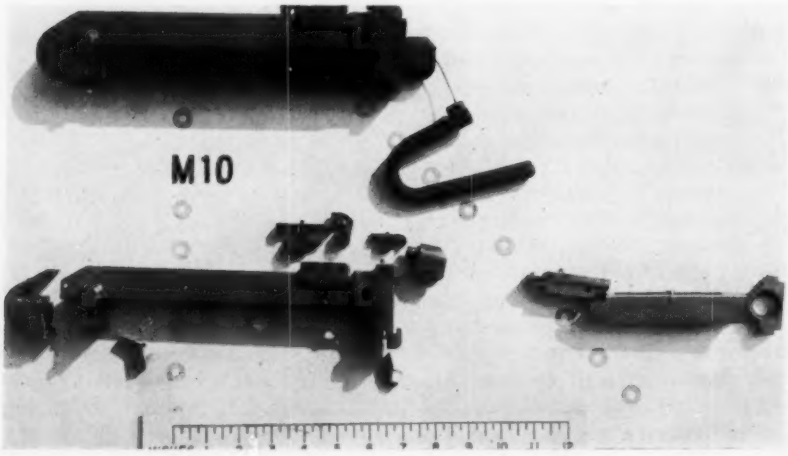
Although ordnance engineers and metallurgists have, on occasion, worked closely with metalcasters, there is a need for better liaison and coordination of efforts. Ordnance scientists carry on continuing research and have made valuable contributions to foundry metallurgy. Their work on ferrous, titanium, molybdenum, vanadium and other tran-



A 356 aluminum housing—part of the Jupiter Missile launcher —and the 18-8 stainless steel linkage used in the azimuth housing. This picture and all photographs showing castings for weapons are U. S. Army Photographs provided by G. D. Chandley, supervisory production metallurgist at the Watertown Arsenal.

G. D. Chandley reports that this group of castings is typical of those used on many programs in recent years. The casting in the center foreground is an intricately cored armor steel unit pressure tested at 7,000 psi. A class C manganese bronze shell mold casting with integrally cast oil grooves is in the left foreground. An aluminum casting with gates and risers is pictured upper rear, and a low carbon steel casting is pictured in the right rear.





A completed M-10 machine gun charger (top) and the exploded sub-assembly. There are 13 shell mold and investment castings used in this one unit. It's main job is to place the first round in the .50 cal. machine gun.

sitional metals has been particularly helpful.

The new era of missiles and rockets provides another challenge to metalcasters. Frequently many components are obsolete before production runs can be planned, but castings are needed now and will be used more extensively in the future.

In one missile system alone, some 1,200,000 pounds of castings are used annually. And this is a relatively small surface-to-air missile. It contains chromium, aluminum, bronze, manganese, iron and steel.

As the missile program progresses, it seems likely that castings will be used in small, mass produced missiles. Forgings are too high priced for this usage.

Air Force Needs

The United States Air Force uses more and more castings for an increasing number of applications. This segment of the ordnance market has shown spectacular growth since jet aircraft development made rapid strides in the past decade.

The planes themselves use castings for rotors and stators, engine mounts, turbine blades, turbine nozzles, rudder actuators, compressor blades, turbine buckets, rocket nozzles and many secondary structures.

Additionally, much of the new ground support equipment calls for complicated parts that can be cast better than fabricated in any other way. Frequently, prototypes or newly accepted designs are cast in preference to other fabrications because of reduced lead time and lower cost.

Looking to the future, ordnance engineers see a need for castings of heavy refractory metals—such as tungsten, zirconium—for parts subjected to high temperatures. They hope for more uniform and reproducible grain structures and improved casting techniques.

It is bluntly stated that wider use of castings will be determined by "the ability of the foundry industry to expand the area of competition with other processing methods."

Contributors to Market Opportunities

The editors of MODERN CASTINGS acknowledge the cooperation and support of Major Gen. W. K. Ghormley, Commanding General, U. S. Army Ordnance Special Weapons-Ammunition Command. General Ghormley and his staff provided the bulk of facts and figures needed to prepare a timely article on a vital subject. The men listed below also provided full cooperation.

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Department of the Navy

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Radioplane Div.
Northrop Corp.
Van Nuys, Calif.

See Business Pick-up Early in 1962

MC Trends Panel charts new gains; reports customers are confident.

Pressure is on for marketing know-how, more cost control, stronger sales push.

Look for spurt in new technology; stiffer quality control requirements.

YOU CAN EXPECT business to pick up substantially the first six months of 1962.

This is the good news from the bellweather MC Panel members, suppliers and metalcasting leaders, who reported on what's ahead for next year. Some 89 per cent of the metalcasters and 91 per cent of the suppliers anticipate increases.

How much will business pick up? There's strong optimism here!

The Panel members based their responses *only on what they think their companies will do* the first six months of 1962, compared with the same months of 1961. Business outlook:

Metalcasters

39 per cent said from 5 to 10 per cent better

44 per cent said from 11 to 20 per cent better

12 per cent said better than 20 per cent

Suppliers

32 per cent said from 5 to 10 per cent better

17 per cent said from 11 to 20 per cent better

37 per cent said better than 20 per cent

Estimates of customer attitudes about 1962 business prospects are also significant. Although both metalcaster and supplier members displayed more conservatism, highly important is that few revealed a generally pessimistic attitude.

. . . 80 per cent of the metalcasting panelists said their customers were generally optimistic, 20 per cent said "generally undecided."

. . . 80 per cent of the supplier panelists said their customers were generally optimistic, 20 per cent generally undecided. (This supplier report is significant in that most metalcasting suppliers also serve other industries than metalcasting.)

Where is the expected gain in business coming from? Answers to this key question produced significant responses. Here again a "bread and butter" answer was required of MC's panel. Each member was asked what factors would contribute to increased sales in his company. The answers:

Metalcasters

70 per cent larger orders from regular customers

67 per cent new business from new sources

32 per cent new products

29 per cent improved products

24 per cent plant improvement or expansion

21 per cent defense contracts or sub-contracts

21 per cent new processes

17 per cent better customer service

Suppliers

66 per cent larger orders from regular customers

57 percent new products

51 per cent new business from new sources

42 per cent from improved products

17 per cent from better customer service

17 per cent from plant improvement or expansion *in 1962*

14 per cent from defense contracts or subcontracts

For most metalcasters and suppliers, the labor situation is expected to be relatively stable in 1962. This is despite predictions for many strikes for many industries. Some 11 per cent of suppliers and 18 per cent of metalcasters (those on the panel responding) expect more labor problems next year but few strikes.

Contrary to expectations, most of MC's panelists reported the General Motors strike and the Berlin crisis have not affected their sales and product plans for 1962.

More Casting Diversification

Is a key trend in the making? From what they have observed, many panelists report that more and more metalcasters are casting *more kinds* of metals.

76 per cent of supplier members have noted this, and 66 per cent of metalcaster members agree.

Opinions concerning this development were diverse, revealing both analytical evaluation and concern.

Supplier Comment . . . This is not necessarily good. Too often new metals are taken on to fill up the shop; and adequate preparations are not made.

. . . Due to some major foundries closing, the remaining are covering themselves to increase their sales and become more flexible.

. . . Nodular coming to both gray iron and malleable shops.

. . . Plants are trying desperately to be competitive by increasing the kinds of metals they cast.

Metalcaster Comment . . . This could be a desirable trend if the effort is to produce better metals as well as more. The emphasis must be on improvement. For a foundry to add just another metal to one now being produced by numerous good competitors is diluting the market for all.

. . . Specialty work and types of metals don't seem to have as much intense price competition.

. . . There is an increased demand from customers to make their products cover wider fields of use by making them in more kinds of metal. Many metalcasters are meeting this demand.

. . . Specialization in castings applications overshadows the benefits of standardization. It takes more kinds of casting methods to do more particular jobs.

. . . We have been (our company) in the midst of this trend since 1955. Management has had the foresight to see the handwriting on the wall. The gray iron casting business indicated a downward trend, especially in our particular field. Too much price cutting was downgrading our business. We turned to the specialty field of alloyed castings, both green sand and shell molds.

Pressure to Know and Use Marketing Methods

How to compete effectively? MODERN CASTINGS asked two exploratory questions of the panel members. The results: 82 per cent of the suppliers and 86 per cent of the metalcasters favored a greater effort to educate all in the metalcasting field in marketing know-how.

A lesser per cent favored seeking a precise definition of marketing as it applied to metalcasting, 63 per cent of suppliers and 50 per cent of metalcasters. Many were undecided, 27 per cent of metalcasters and 17 per cent of suppliers.

An outstanding supplier to the industry says: "If it means to arrive at a precise definition of what they (the metalcasters) have to do to sell their products, *YES*."

Executive and Worker Training in 1962

A question about the need for training and retraining brought forth:

Metalcaster Opinion

	Much Emphasis	Some Emphasis
Supervisors and Foremen	49%	26%
Middle Management	39%	46%
Plant Workers	24%	32%
Top Management	15%	39%
Office Personnel	9%	33%

Supplier Opinion

	Much Emphasis	Some Emphasis
Supervisors and Foremen	60%	20%
Middle Management	60%	23%
Top Management	45%	32%
Plant Workers	32%	32%
Office Personnel	29%	23%

Metalcaster Comment . . . Plant workers, supervisors and foremen need continuous training because we are constantly changing methods and systems to produce better castings at lower cost.

. . . To get more work from plant people we need better trained management people.

. . . Adequate training facilities are hard to come by, particularly for small companies.

Supplier Comment . . . Fifty per cent of all our employees are currently enlisted in some form of schooling or training program.

. . . Our industry and economy will be subjected to more changing patterns than ever before.

. . . Lack of knowledge by top management is causing increased costs due to poor quality, more scrap.

. . . The constant rise and fall in the labor force requires a continuous training of production workers added to the force. Let's face it! We all need continuous training!

Key Trends of 1962

What metalcasting trends does the MC Panel think will speed up in 1962? Opinions vary. This diversity is among metalcaster and supplier members alike:

Metalcasters

Trend	Will Speed Up	Pace About Same
Quality control	77%	23%
Cost control	76%	23%
Sales efforts	70%	30%
Mechanization	59%	41%
Customer diversification (more kinds)	52%	38%
Captive plants seeking outside customers	50%	36%
Small plant casting specialization	36%	44%
Employee training	34%	66%
Company mergers	29%	49%
Captive foundries closing with plants buying on the outside from jobbers	29%	42%

Suppliers

Mechanization	83%	11%
Sales efforts	74%	17%
Quality control	72%	17%
Cost control	72%	23%
Customer diversification	57%	26%
Employee training	49%	43%
Captive plants seeking outside customers	46%	40%
Casting specialization by small plants	40%	46%
Company mergers	32%	51%
Captive foundries closing with plants buying on the outside from jobbing plants	27%	34%

Shell Molding and Ductile Iron—New Profit-Making Team

Product reliability and automated mass production are two major benefits realized by Ford Motor Co. There are many plus advantages—time, materials, and health saved—which can be attributed directly to this new technology.

By ARTHUR A. ADAMS
HAROLD GRANT
Ford Motor Co.
Dearborn, Mich.

CRANKSHAFTS by the millions —already more than 23,000,000—are dynamic proof of Ford Motor Company's profitable wedding of two new technologies.

The Dearborn Specialty Foundry has engineered product reliability into every ductile iron crankshaft it produces. Shell molding, in turn, has provided flexibility that permits automated mass production of superior designs with exacting dimensional accuracy.

Ductile iron is blessed with the right properties for optimum crankshaft performance — wear resistance, damping capacity, machinability, castability, and endurance. These form a profitable team setting new performance standards for passenger car crankshafts with significant cost reduction over competitive materials and processes.

The outstanding advantage of the shell molded crankshaft is the manner in which the entire process responds to a high degree of automation. Automation begins in the melting area where ductile iron is produced continuously from advanced design cupolas and continues throughout the molding, cleaning, and inspection operations.

Sand requirements have been reduced from 125 pounds per casting in the previous core sand casting method to 20 pounds per casting using shell molding. This conserves a near strategic mineral—good foundry sand—and simplifies the problem of refuse sand disposal, with or without sand reclamation.

A further very important benefit of shell molding to Specialty Foundry, where it is used exclusively, has been to provide vastly improved working conditions. Minimizing the amount of sand required in the molding system has reduced hard manual labor. General cleanliness of the castings have contributed much to a cleaner, less fatiguing, quieter, safer, healthier operation.

Free Skilled Men

Of equal importance are secondary considerations which allow more effective utilization of skilled foundry engineers. In the process employed by Ford, uniform feeding characteristics are obtained. As a result, sound, shrink-and-defect-free castings are consistently produced with no major changes in pattern gating required.

Further, foundry engineering required to meet quality standards during model change-over has been substantially eliminated. Experience has shown the process to require less pattern maintenance. None of the many patterns used in casting crankshafts have been replaced because of excessive foundry wear.

Very close tolerances are maintained from casting to casting. Improved uniformity produces dimensionally near-perfect crankshafts and allows effective use of quality control procedures for inspection, gaging, and metallurgical examination. This is particularly important in that no qualification of the locating points used in the machining operations is necessary.

The rough crankshaft as delivered to the machining operations is distinctly superior to that available from any other fabrication method. Ford manufacturing engineers have been able to utilize process characteristics to further reduce manufacturing cost. The increased precision of the casting has resulted in a reduction in the finish stock from 9.5 pounds in the previous casting practice to 5.5 pounds in the shell molding process. The complete transition from the forged shaft to the shell molded shaft resulted in a 70 per cent reduction in the weight of the chips produced. The influence of this spectacular reduc-

tion on machine cycle time and minute cost is obvious.

Increased precision with absence of warpage allows fast traverse in many machining operations until actual contact is made between the tool and the work piece.

Closer tolerances available in this casting procedure also improve the balancing operation. Here, by very close control of the balance weight location in the original casting, preliminary balance has been eliminated. Final balance has been typically limited to drilling a 7/8 inch diameter hole less than one inch deep into the end counterweights. The centering operation has been simplified by control of mass location and the need for mass centering machines has been eliminated. Present practice uses geometric centering entirely.

No Machining

In one year, over a million crankshafts with an allowable 0.0285 inch clearance between the crank cheek outside diameter and the camshaft distributor gear were assembled into engines without machining at this location.

The outstanding engineering property of the shell molded ductile iron crankshaft is wear resistance. It has the best wear resistance of any materials used in Ford's automotive crankshaft manufacture, and this is attributable to the self-lubricating property of the free graphite on the bearing surface.

A second important engineering characteristic is exceptional endurance based on simulated service tests and field results.

A third valuable engineering advantage results from the design flexibility of precision shell casting which:

(1) Allows more efficient distribution of weight.

(2) Contributes to engine compactness.

(3) Permits freedom in contouring sections.

In the melting department, the selection of refractories are a paramount consideration. Ford's cupola's are water-cooled with a carbon block lining in the well. This lining is neutral and fairly inert. The block linings last at least two years—some have been used for six years—and eroded areas are repaired once each week with carbon paste. Tap hole and bottom is replaced weekly when the bottom is dropped.

The cupolas are of the offset well design. From the sill plate up to three feet, the well is offset to allow carbon blocks to be installed without altering the inside diameter of the cupola. The shell extends 14 feet from this area on a slight angle from 90 inches inside diameter to 80 inches inside diameter. At this point, cast ductile iron cupola blocks are installed.

These blocks protect the shell from abrasive action by the bottom-drop, cone charging bucket. This area extends five feet above and below the charging door sill. Fire brick with fireclay is installed above this area to the top of the stack.

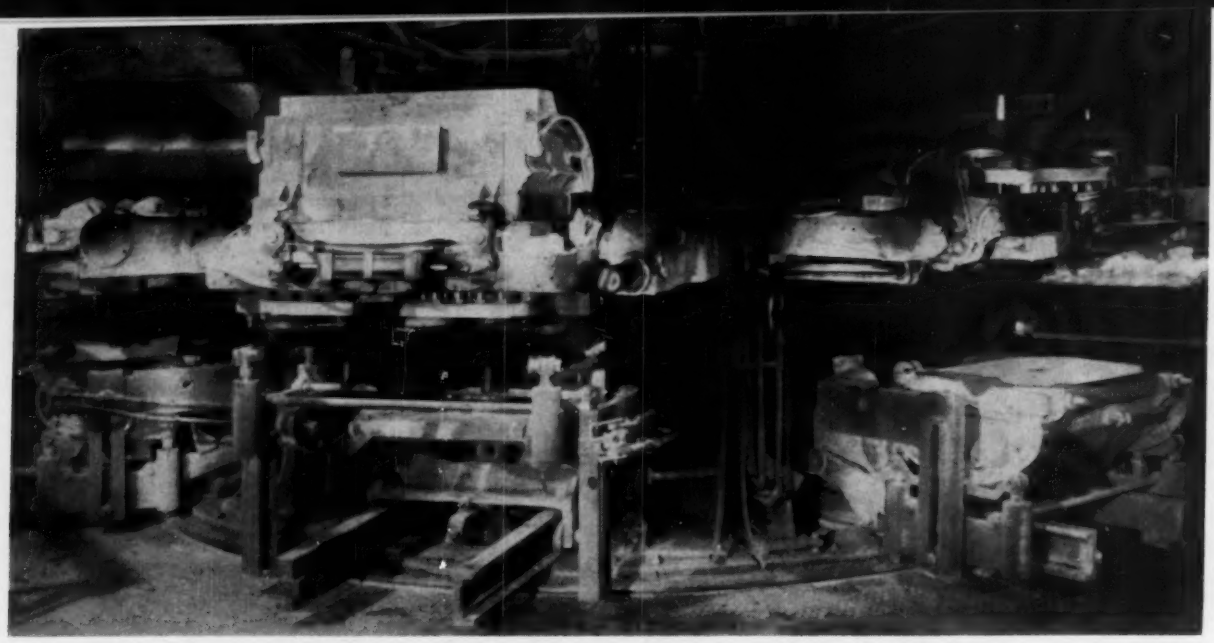
Front slaggers are lined with monolithic graphitic plastic fireclay with a minimum 13 per cent graphite. This is broken into small pieces and rammed into the bottom of the front slagger three inches at a time with a pean-head, bench type pneumatic sand rammer. Prior to applying the next layer, the first is scarfed. Forms are placed into the front slagger after the bottom is completed, and succeeding layers of refractory are applied. The front slagger is fire cured in about 24 hours.

Save on Charge

Ford operates a neutral, carbon-lined cupola with a basic slag. This permits use of less expensive charge materials, yet produces the low-sulphur, high-carbon iron ideally suited for making the crankshafts. Eight-ton, gas-fired forehearths are large enough to maintain a homogeneous metal bath at a constant level, yet small enough to prevent severe temperature drop.

The forehearths withstand erosion and thermal shock from the continuous flow of metal from the cupola. They are lined with chrome-free MgO material containing approximately 80 per cent minimum magnesia. Linear

Each pair of shells produces two crankshafts. A single pattern can be used for both halves of a completed assembly.



Six individually activated shell molding machines are mounted on a huge turntable. The entire shell making operation is performed during a single rotation of this table—including pattern preheating.

change is seven per cent maximum shrinkage, and apparent porosity is 10.15 per cent. The material is rammed to an approximate nine-inch thickness on the forehearth shell, three inches at a time, and cured 800° an hour until it reaches 2000°F.

Ladles are lined with a mixture of sharp sand, rounded sand, bentonite fireclay, water and glutrin. Every ladle of iron is skimmed and dross raked off before pouring. The ladle is scarfed and dumped after every fifth heat to prevent a rapid buildup of the lining.

Cupola Control

Successful production starts with careful cupola operations. The cupola bottom is made with an 8-inch layer of sand and an 8-in layer of basic refractory material uniformly rammed to a hard surface, with a wide fillet and a one-inch-to-the-foot slope to the tap hole.

Scrap cardboard boxes are placed over the newly prepared bottom to protect it from falling coke, then the bed is built up to a point four feet about the tuyeres. Gas igniters are moved from tuyere to tuyere until the coke at each tuyere area is completely ignited. Tuyere doors are closed and a low air blast of 2000 cfm turned on. The tap hole is left open to insure complete ignition of coke below tuyere area. Additional coke is not added until the first coke has been completely ignited.

For a conventional operation, the ideal bed height will be approximately 10½ times the square root of the wind box pressure added to six. Once the bed height is established a height gauge is used.

The metal-to-coke ratio varies with the carbon pickup required and the extent of reducing condition desired. Statistical quality control charts measure coke properties. The Shewhart chart is used for the control of one variable per chart. (To control six variables, six charts are used. Samples of a constant size are taken at regular intervals—every hour, every four hours, every day. The average of these samples is plotted on a chart. This will establish the capability of the process, or, in the case of incoming material, of the supplier's process.

Bar-graphs and histograms are used to show distribution curves and central tendencies. Each shipment of coke is inspected for slate, ashes, and foreign matter. It must be strong enough to sustain the weight of subsequent charges in the cupola stack, of proper diameter and wind control, and low in volatile matter for slag control. Control charts are kept on the cokes from each supplier to verify these qualities.

Coke strength is checked by dropping a 50 pound sample of coke six feet, four times and determining the percentage retained on a two-inch screen.

Size is controlled by a sieve test in which there must be a minimum of 45 per cent on a 6-inch screen, 70 per cent on a 5-inch screen, 89 per cent on a 4-inch screen, 91 per cent on a 3-inch screen, and 98 per cent on a 2-inch screen. These percentages are cumulative.

Coke Conforms

Ford's foundry coke must conform to the following specifications: (1) 91 per cent average minimum fixed carbon, (2) 9 per cent maximum ash, (3) 2 per cent volatile matter, (4) 7 per cent sulphur, and (5) 0.03 per cent phosphorous.

Other non-metallics comprising the cupola burden are limestone and fluorspar. These components are rigidly controlled to

maintain an accurate slag-to-metal ratio.

Limestone breaks down into calcium oxide, works its way through the coke, cleans the ash from the coke, unites with the other impurities in the charge, and establishes basicity. It produces slag which must be rendered more fluid, or it has a tendency to form bridges which slow up the cupola melting rate. This causes excessive oxidation and cold metal. Fluorspar, or spar as it is commonly called, thins the slag and causes the formation of a more fluid, chemically active slag which flows freely from the cupola. Spar is used in smaller quantities than limestone due to its corrosive effect on refractories in front slaggers.

Fluorspar by Agreement

Control of fluorspar is maintained through purchase agreements guaranteeing an acid grade spar with a 91.90 per cent minimum effective CaF_2. A representative sample is taken from every carload on arrival, and complete analysis is made.

The metallic materials which make up the cupola burden are back scrap, steel scrap, silicon pig, and Mn alloy. Gates, risers, runners and sprues are back scrap. Steel scrap, low in carbon and free of high alloy steel is purchased. Size, excessive dirt, organic materials, and undesirable alloys are checked. Any questionable materials are analyzed spectographically. A periodic check is also made of the basicity ratio of the cupola slag. Analysis of manganese oxide in the slag indicates degree of oxidation. Slag is checked at 15 minute intervals for basicity and disintegrating characteristics. If the slag begins to turn, the charging is altered.

Base metal for making ductile iron is mixed in an eight-ton forehearth. Analysis runs 3.60-4.10 per cent carbon, 2.0-2.30 silicon, 0.70-0.90 manganese, 0.25 maximum chrome, 0.015 sulphur, 0.04 maximum phosphorous, and 0.70 maximum copper.

Every 30 minutes a sample is poured into a shell mold for spectrographic analysis. Only metallic elements whose atomic weights are 24 or higher are checked in the spectrograph. Metal is tapped into one-ton bull ladles where it is treated with the nodulizing inoculants.

Control personnel take spectrograph pin samples from each ladle for final analysis. The top part of the pin mold provides a fracture bar which serves as an immediate check of nodularity at the pouring line. Improper response indicates the presence of subversive elements, excessive oxidation of the magnesium (decay) or the presence of excessive sulphur. All or any of these conditions necessitate removal of the ladle from the pouring line.

Hot coated sand with phenolic crushed novalacs are used for shell molds. Resins are checked on delivery for four characteristics:

1. Resin particle size.
2. Softening point or melt point—95 to 105°C (with 14 per cent Hexa added).
3. Inclined plate flow (with 14 per cent Hexa added) 20 to 30 MM.
4. Film cure rate (with 14 per cent Hexa added) 69 to 75 seconds.

Sand is analyzed for clay content, combustibles and screen size. It has an AFS fineness of 90-105 and is predominately three-screen. Specifications call for one per cent maximum clay (desired) and one per cent maximum combustibles.

Six Shell Machines

Hot sand is mixed with 4.25 per cent resin plus 15 per cent Hexa for 90 seconds in a pug mill and two and one-half minutes in a muller. A pound of wax is added near the end of the mix cycle for parting. Tensiles average from 500 to 530 psi.

The crankshaft shell molds are made on six shell making machines mounted on a large turntable. Patterns are continuously cycled through the various stations — preheating, application of liquid parting agent, dump coating with coated sand to form 3/16-inch semi-plastic shell. The last application is possible because the pattern is trunion mounted and rotates around a horizontal axis independent of the turntable. Final cure of the thin shell takes place as the machine is rotated under a radiant heater. It is then automatically stripped from the pattern and manually transferred to the assembly table.

Each pair of shells produce two crankshafts, so each two-minute rotation of the turntable makes shells for six crankshafts.

Interchangeable Patterns

Unique pattern design allows complete interchangeability of all patterns for identical crankshafts. The casting symmetry is such that by mounting both pattern segments as right- and left-hand members of the pattern assembly, a single pattern can be used for both halves of a completed assembly. Two randomly selected shells are joined together by spring loaded clips and inserted into an open top, bottom hinged, basically rectangular flask mounted on the pouring line.

The flask is carried to the loading station where an overhead gravity hopper drops commercial cleaning shot into the flask cavities to support the thin shell mold against the internal pressure of the molten iron. The flask is then advanced to the pouring station where molten iron is poured into the molds. The castings continue on the pouring line for an additional 30 minutes until they reach the shakeout station. Here the castings, plus gates and risers, are transferred to a cooling conveyor. The castings proceed through cleaning, break-off and inspection operations and then to the shipping station.

All automobiles produced by the Ford Motor Co. use ductile iron crankshafts. Physical endurance and monetary benefits indicate that it will take a major breakthrough in metalcasting technology to convince the company that another metal or another process is better suited.

Getting the most mileage out of a grinding wheel involves the human element as well as the quality of the materials being used.

Metal shot performance should be compared against a par of past experience. Good records will give the details needed to make the comparison.

MODERN CASTINGS on-the-job survey tells how metalcasting managers control costs by . . .

Evaluating Cleaning Room Materials

MATERIALS QUALITY control records are one form of holding down costs in the cleaning room.

These records pinpoint daily costs and serve as a reliable guide to sound purchasing—so say superintendents and cleaning room foremen at many foundries throughout the country.

MODERN CASTINGS, in an on-the-job survey of plants ranging from small to large, learned that management looks upon the cleaning room as one of the trouble areas in controlling costs. This operation too often represents a critical bottleneck in an otherwise smooth metalcasting production line. It also contributes a sizeable chunk to the total casting expense, yet it defies automation in most cases and resists all but a minimum of mechanization.

The superintendents and foremen agreed that misuse of grinding wheels and metal shot can quickly erode profits. This is why they have made every effort to bring about a program of control over the cost of the materials.

The casual observer sees grinding wheels and metal shot as similar products doing a similar job. The fact is—they are not the same. One type can out-perform another, sometimes by a factor of 100 per cent or more! Evaluating this performance is a tough job. It is always complicated by the element of human skill which can make or break the performance of cleaning room supplies.

Modern shops have developed production standards for every operation performed on a casting in order to arrive at equitable piece-work labor rates. In the cleaning room, standard hours of productivity may be based on cents-per-hour-per-linear-inch of metal removed for grinding and snagging work. The broad spread of human skill is a major cost factor. An eastern foundry tells of their top grinder producing 16 standard hours of work in an eight hour day when others are not able to produce eight standard hours in the same length of time.

Where does one start in this job of evaluating cleaning room materials? In most foundries visited, material performance standards are based on a very reliable common denominator—*past experience*. If adequate records are kept, it is not difficult to set up "life expectancy" parameters to judge present day performance. These records show, in the case of metal grinding, the amounts of metal removed, the wheel wear, the labor expended, and the cost of the wheel. Each foundry

must decide from its own records how it wants to compromise on these four variables. A happy medium may be the answer to this dilemma.

Foundry superintendents are always under pressure by vendors to try the newest super-duty, high-performance materials. The fair minded operator recognizes that nothing is so good that it cannot be better. But how can he make a fair comparison between competitive products? This is the question asked of many foundrymen. In most instances they do a remarkable job of counter-balancing the uncontrollable variables that plague cleaning room operations to make a fair test. A Syracuse foundry assigns two men to work alternately on the wheel undergoing tests. This levels out the influence of human element. If possible they grind castings on which previous records are available.

Records Show Life Expectancy

Past records may show that a 24-inch by 2-inch wheel should have a life expectancy of 200 wheel hours and 270,000 pounds of castings ground. Accumulative records are kept on the wheel under test. The cost of the new wheel, the pounds of castings ground or metal removed, and the standard earned hours are then compared with data accumulated on grinding wheels currently in use in the shop. Armed with this data the superintendent or cleaning room foreman has a lot less trouble making the right purchasing decision—and can back it up with facts.

Some of the bigger malleable shops make more sophisticated comparisons by setting up carefully controlled experiments. The material removed by grinding is carefully collected and weighed, wheel diameter is frequently measured, and power consumption is documented with a recording watt meter.

One foundry gets more mileage out of its wheels by wearing 24 inch wheels down to 16 inches then transferring them to other grinding machines. When wheels wear to 11 inches they are scrapped.

A resourceful Michigan foundry cut grinding wheel costs substantially by ordering wheels with a bigger hole in the center. They reasoned that there was no sense paying for expensive abrasive in the center of the wheel where it could never be used, so why not eliminate it!

Aluminum foundries are more apt to be concerned with evaluation of grinding belts. One large shop starts a comparison program by having the salesman deliver five duplicate belts to be tested. Three reliable experienced grinders are assigned to three machines equipped with the new belts. If productivity and the other elements measure up to past performance standards, the salesman is given an order for 50 belts. If the 50-belt sample out-performs the current standard, the cleaning room converts to the new belt.

As in the case of grinding wheels, metal shot performance should be compared against a par of past experience.

A good set of records on each cleaning machine should include hours of operation, weight of shot added, weight and part number of each job cleaned, labor charges, and costs of replacement parts. You know where you have been and what direction you are headed in on a daily, weekly, and monthly cost basis. The figure for the pounds of shot consumed per hour and per ton of castings cleaned is the one that tells the story.

Making a comparison between competitive brands means a foundry should purchase enough shot to fill the system and keep it fed for the duration of the test. Performance records should be kept and compared with past performance. The dollar cost for the pounds of shot consumed per ton of castings cleaned is a reliable guide in making the next purchase.

In one instance a foundry had duplicate machines with a different brand of shot running in each. This provided a convenient daily comparison throughout the eight-month duration of their evaluation program.

These records have value in policing daily operations and maintaining a quality check on shipments of material from any one supplier. The human element in this operation is minimal compared to grinding, but there is the strong influence of attentive maintenance on shot consumption. Let the cleaning machine get out of adjustment, and costs rise quickly.

Dirty Shot Means Lost Dollars

Poorly cleaned shot means sand contamination which leads to excessive wear on equipment and inefficient removal of sand adhering to the cast surfaces. Time and money are lost running the castings through the cleaning equipment a second and third time. Improperly adjusted separators can tip the balance the other way so that shot is lost along with the sand being removed. Any time the rate of shot consumption goes above normal, a maintenance man should be called to check this adjustment.

The practice of taking a screen analysis once a week prevents a gradual build-up of sand in the metal shot. Keep sand content down to three per cent; five per cent is permissible; but 10 per cent sand in the shot is damaging the equipment, and cleaning efficiency is bound to be low.

Some foundries equip the blast cleaning equipment with hour-meters and amperage recorders to provide a running record of cleaning efficiency. If the ampere reading falls off, the operator knows that the machine needs more shot. He may better clean the screens which could be plugged with sand, core butts, rods, and wires. Cleaning screens permit shot to flow back into the system.

The consensus of experience points up fringe benefits which result from a good set of quality control records. Not only do records keep a thumb on daily costs, but they serve as a reliable guide to sound purchasing practices—a two-way benefit in cost control.

Prompt servicing of materials handling equipment insures its operating efficiency. Good records reduce maintenance costs.

How to Cut Downtime on Handling Equipment

√ *Provide periodic checks where minor troubles are spotted before they cause equipment failures.*

√ *Furnish accurate operating costs on each piece of equipment so management can decide whether to replace or overhaul it.*

√ *Increase efficiency of mechanics by providing them with service check lists to systematize their work.*

√ *Reduce overall maintenance costs by organizing work.*

√ *Provide purchasing department with means of accurately forecasting purchases of normal wear items.*

By JOHN M. SQUIER
Clark Equipment Co.

YOU CAN'T HELP saving money and time if you keep materials handling equipment at top operating efficiency.

Unscheduled down time on a foundry lift truck or conveyor system is a costly proposition that can be avoided by a simple system of keeping and analyzing maintenance records on every piece of handling equipment in the plant.

Accurate records on maintaining and servicing handling equipment give these results:

(1) Reduce unscheduled equipment downtime by providing periodic checks where minor troubles are spotted before they cause equipment failures.

(2) Furnish accurate operating costs on each piece of equipment so management can decide whether to replace or overhaul it.

(3) Increase efficiency of mechanics by providing them with service check lists which will systematize their work.

(4) Reduce overall maintenance costs by organizing work.

(5) Provide purchasing department with means of accurately forecasting purchases of normal wear items.

The success of the program depends on a well-kept record of each machine. This should include every bit of information that will insure the wisest use of equipment at the lowest cost. This includes:

Serial number, capacity, make and type.
Date machine was placed in service.
Where and how equipment was used.
Number of hours or miles logged daily.
Record of scheduled maintenance, including nature of repairs.
Record of unscheduled maintenance, including nature of repairs.
Name of mechanic who serviced equipment.
Record of time spent on each maintenance operation.
Record of all parts used (number and cost).
Record of fuel and oil consumed.

This maintenance check list should be used at periodic intervals, based upon the number of hours or miles each machine operates. Schedules will vary with different operations but inspection and servicing are suggested at four intervals—after 8, 40, 500, and 1000 miles of truck operation.

Since periodic servicing is based upon the hours each machine operates, an hour meter on each piece of materials handling equipment is an indispensable tool. The hour meter, a main link between records and machines, can be supplied by most manufacturers.

Without knowing either the hours or miles a machine operates, there is no accurate way of knowing when basic servicing or major servicing is due.

Knowing the hours or mileage equipment is operated enables the maintenance supervisor to consult the service check list to determine the recommended servicing due.

These checklists can be established by plant personnel, based on individual plant experience and problems, but it is wise to consult with the equipment manufacturer for factory recommendations in each case.

Most manufacturers publish check lists which can be followed or used as a basis for setting up your own list.

Often individual foundries have peculiar operating problems requiring special tailoring of check lists. In such cases, the manufacturer can help by

surveying the operation and making specific recommendations. Larger plants use a driver service order in addition to check lists.

If record keeping is done by a mechanic, forms and check lists should make it easy to record data and make his job easier.

Record keeping systems vary according to individual operations or references of service personnel. Regardless of the technique, the most important requirement is that the records be kept and that complete maintenance information is centralized and easily accessible. Once record keeping has been established, maintenance personnel should be supervised to insure that all requested information is recorded.

It is important that the records provide all necessary information for evaluating the entire materials handling operation from a cost standpoint. To determine if these records are complete, ask these four questions:

(1) Do records show when machines were purchased and how many hours or miles per month each unit operates?

(2) Do records provide an accurate account of money spent on each machine for maintenance and fuel?

(3) Does maintenance department have a check list of major points to inspect at each daily, weekly, and other servicing periods?

(4) Is all unscheduled downtime reported accurately so that responsibility can be fixed?

If each question can be answered affirmatively, chances are the maintenance program is functioning.

No maintenance program is so complete that breakdowns will be eliminated entirely. But a well-administered program can reduce unscheduled equipment downtown to a minimum. Good record keeping enables a supervisor to fix responsibility.

A properly supervised and documented maintenance program is one of the best possible investments of management time when contrasted with the high costs of unscheduled downtime and disorganized maintenance.

The check list at the right is a miniature example of a form which is used to keep gas and electric fork lift trucks and towing tractors in top operating efficiency. It shows all operations performed at 8, 40, 300 (or 500) and 1000-hour intervals. General areas covered include: drive axle and differential, brakes, clutch or automatic transmission, cooling systems, electrical system, engine, fuel system, hydraulic system, steering and miscellaneous.

INSPECTION AND SERVICE ORDER
GAS AND ELECTRIC FORK TRUCKS AND TOWING TRACTORS

DRIVE AXLE AND DIFFERENTIAL	8	40	300	1000
Clean and Repack Gears and Bearings				■
Wheel Ends (Hypoid Axles)				■
Check Oil Level		■		
Drain and Refill				■
Drive Axle Air Vent		■		

BRAKES					
Service Brakes	■				
Seat Brake	○				
Master Cylinder and Lines		■			
Check Shoes Linings and Connections					■
Brake Adjustment					■
Check Hand Brake or Brake Lock	■				
Power Brakes (Hydrovac & Air Cleaner)					⊠

CLUTCH OR DYNATORK DRIVE					
Throwout Bearing Grease Cup	⊠				
Clutch Pedal Adjustment		⊠			
DYNATORK DRIVE: CLEAN HOUSING SCREENS BRUSHES & COLLECTOR RINGS		⊠			

COOLING SYSTEM					
Radiator, Water Level & Anti-Freeze	⊠				
Examine Core, Hoses, Check for Leaks		⊠			
Water Pump, Check Lube and Mounting			⊠		
Fan and Fan Belt Tension		⊠			

ELECTRICAL SYSTEM					
WATER LEVEL, HYDROMETER READING CABLES, RECEPTICLE AND TERMINALS	○				
WATER LEVEL, HYDROMETER READING CABLES, AND TERMINALS		⊠			
Pump and Drive Motor Brushes			○		
PUMP AND DRIVE MOTOR: INSPECT, CLEAN AND REPACK OR REPLACE BEARINGS				○	
Gauges Ammeter and Etc.	■				
Contactor Panel, Clean & Adjust Points		○			
Generator Lubrication		⊠			
Starting Motor Lubrication			⊠		
Gen. and Start. Motor. Check Brushes			⊠		
Lubricate Distributor		⊠			
DISTRIBUTOR: ADJUST POINTS INSPECT ROTOR, CAP & CONDENSER			⊠		
Ignition Timing			⊠		
Spark Plugs: Check Gap & Clean			⊠		

ENGINE					
Check Crankcase Level	⊠				
Drain Oil & Refill, Check Oil Filter		⊠			
Valve Tappets, Inspect & Adjust			⊠		
Engine Compression			⊠		
Cylinder Head Nuts, Gasket & Leaks			⊠		
Manifold, Nuts, Gaskets & Leaks			⊠		
Muffler, Mounting, Condition			⊠		
Governor, Speed & Surge			⊠		

FUEL SYSTEM	8	40	300	1000
Carburetor Adjustment			⊠	
Air Cleaner	⊠			
Fuel Pump		⊠		
Fuel Supply	⊠			
Fuel Filter Cap: Clean Screen		⊠		
Check Fuel Oil Filters (Diesel Only)		⊠		

HYDRAULIC SYSTEM (NOT TOWING TRACTORS)					
Operation Tilt & Lift: Oil Level	■				
Check Pump, Valve & Tank		■			
Clean Tank Filler Cap		■			
Lift Chain Adjustment		■			
Lift Brackets and Slides					■
Check Tilt & Lift Cylinder Drift					■
TILT CYLINDER: CHECK GLANDS, BOOTS, MOUNTING PINS					■
Lift Cylinder, Packing Boots & Vent					■
Inner Slides (Lubricate)		■			
Inspect Lift Forks					■

STEERING SYSTEM					
Wheel Bearings					■
Axle Grease Fittings		■			
Steering Gear, Lube & Mounting		■			
Drag Link Adjustment					■
Check Turning Radius					■
Inspect Tie Rod Ends					■
Inspect Pivot Pins & Spindles					■
Power Steering: Pump & Valve					⊠
Power Steering Booster					⊠

TRANSMISSION					
Hydratork: Check Oil Level	⊠				
Hydratork: Drain and Refill					⊠
Hydratork: Check Oil Pressure			⊠		
Standard: Drain & Refill			*		⊠
Standard: Check Level	⊠				
Drop Gear Case, Check Level					⊠

MISCELLANEOUS					
Check Electrical Connections and Tips			○		
Check Tires	■				
Lights: Head and Stop	■				
Lubricate All Grease Fittings			■		
Miscellaneous Linkage & Clevis			■		
Steam Clean Machine			■		
Inspect Spring Shackles U Bolts & Clips					■
Tighten All Bolts, Nuts & Capscrews					■
Inspect U Joints					⊠
CHECK FLUID COUPLING (GAS TOWING TRACTORS ONLY)					⊠

DATE _____ MACHINE SERIAL NO. _____
DRIVER _____
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CODE: All Machines ■ Gas Models ⊠ Electric Models ⊡

Time Intervals For Inspection Are Either _____ 8 40 300 1000

REMARKS _____

372-Z

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Why Grain Refinement Is Important Today

1. *As metalcasting technology advances, grain refinement assumes greater significance in the production of quality castings.*

2. *Engineers in many industries are turning to metalcasters as possible sources of supply for new parts and new products. In turn, the metalcasters are placing greater emphasis on sales engineering to broaden their markets.*

3. *New performance levels are demanded, and research into the very heart of the metal is necessary to provide metalcasting with the versatility it needs to meet new requirements.*

4. *Research provided the tools for better control of grain refinement, and new industrial applications for castings puts an added incentive behind the search for even more exacting controls.*

5. *Grain refinement progress is not as immediately dramatic as some phases of metallurgy—but it will have a lasting impact on both ferrous and nonferrous metalcasting. New methods of mechanical vibration, inoculation, and the use of additives will provide greater strength and reduce brittleness in castings.*

This article is abstracted from the official AFS exchange paper presented at the International Foundry Congress in Zurich, Switzerland. The complete study was prepared by J. F. Wallace, associate professor; G. W. Form, assistant professor; G. K. Turnbull, G. Gould and H. Merchant, all of the Department of Metallurgical Engineering, Case Institute of Technology.

IN CASTINGS, the size and shape of grains formed during freezing are of particular concern to the metalcaster since many facets of a coarse, as-cast structure cannot be modified through subsequent treatment.

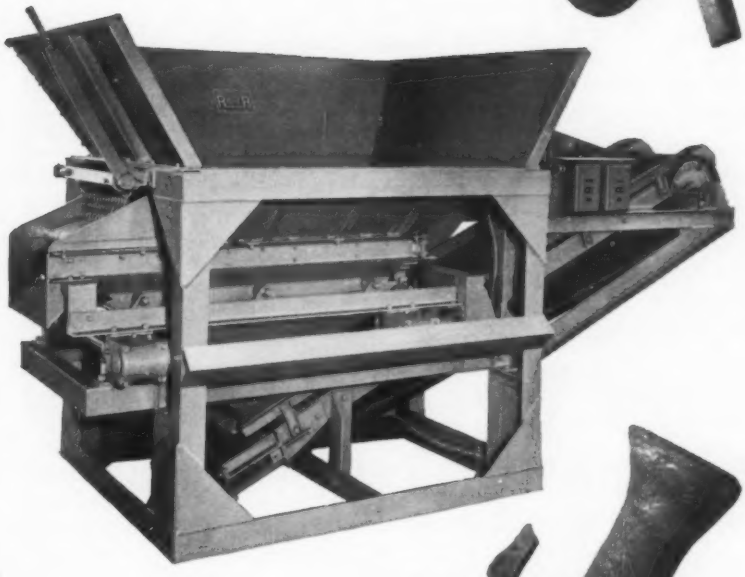
Results of recent studies on the effect of mechanical vibration as well as inoculants and additions for the purpose of grain growth restriction in copper, gray iron, and steel are presented here.

To determine the effect of vibration on grain refinement and the resulting mechanical properties, a tapered ingot mold was used. This was a steel tube, 8 in. long with a 4.5 in. inside diameter welded to a steel plate with a hollow cooling chamber. Both sonic (60c) and ultra-sonic (20kc) vibrations were applied using an electro-magnetic vibrator for sonic and a 110 watt magneto-strictive generator for ultra sonic vibration.

The mechanical properties and grain size of several alloys are summarized in Table 1. Except for the non-ferrous metals, already grain refined by inoculation (titanium in aluminum base alloys), or a grain refiner in the regular composition (iron in high strength yellow brass), considerable refinement resulted when the solidifying melt was vibrated. The finer grain size improved strength and hardness; in some cases better ductility was observed.

There is some variation in grain size between ingots vibrated at 60c and those vibrated at 20kc. But the variation must

TRAMP TRAMP TRAMP



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be attributed to the difference in vibrational energy between the sonic and ultra-sonic technique, not to a frequency effect. Grain refinement produced by vibration is virtually independent of frequency and principally controlled by the energy intensity.[1]

The theory is that vibration produces alternate pressure and rarefaction waves in the solidifying melt. These variations in pressure produce additional sites of easy nucleation.

For metals which contract on freezing, a given change in pressure will raise the melting temperature more effectively, the larger the volume change of freezing, the greater the effect. As a result the degree of undercooling increases to more pronounced grain refinement.

Experimental evidence supports the assumption that alternating pressure or rarefaction waves, through mechanical vibration, bring about grain refinement.

These same pressure waves can also coarsen constituents in vibrated anomalous Al-Si and Fe-C eutectic alloys. Initially vibration increases the nucleation centers for the growth of eutectic cells and leads to a cell refinement by raising the temperature of rapid nucleation. The temperature at which eutectic solidification proceeds is raised over that of unvibrated anomalous eutectics.

At this higher temperature the driving force for growth (difference in bulk free energy between liquid and solid phase) is less, so the steady state conditions for growth will be shifted in the direction of coarser particles in an attempt to minimize the total interfacial energy between the eutectic constituents.

The commonest method of refining the as-cast grain size is to add one or several substances to the melt.

Electrolytic Copper Used

One of the base metals studied was electrolytic copper containing about 0.12 percent residual impurities. The melts were prepared in a clay-graphite crucible inserted into a gas-fired furnace. To establish a common basis for comparison, the following procedure was employed, unless specifically stated otherwise:

1. Deoxidation with 0.050 weight percent phosphorus added as 15 percent phos-copper
2. Insertion of the addition just before pouring by using a refractory plunger
3. Control of superheat at 2200°F and pouring temperature at 2100°F
4. Use of a mold assembly which consistently produced columnar solidification in the unmodified copper ingot. The tapered steel mold was preheated to 400°F prior to pouring.

Additions made to molten copper were inoculants or growth inhibitors. Some inoculants were of the cubic crystal structure to provide good matching with solid copper. Others, with a more complex structure, were also added.

All inoculants were supposedly stable solids at the melting temperature of copper. The substances required to produce the inoculants of a more complex type were introduced into the melt by a double addition method which produced finely distributed solid particles by an exothermic reaction.

Grain growth inhibitors were selected for their constitutional supercooling potency shown by an equilibrium diagram. A small distribution coefficient and a large freezing range was desired to obtain effective action. Selenium and tellurium were also added. According to the adsorption theory[2] they exert the strongest "screening action" on growing copper crystals.

Cobalt and iron form a low-concentration peritectic with copper, however, if they are added in amounts too small for the peritectic reaction to occur, they can be classified either as inoculants or grain growth inhibitors. Classification depends on whether they were added un-

(Continued on page 64)

TABLE 1

Average Mechanical Properties and Grain Size of Vibrated and Unvibrated Ingots

Alloy	Vibration Conditions	Avg. Grain Diameter mm	Tensile Strength Psi	Yield Strength (0.2% offset) Psi	Elongation %	Reduction in Area %	Hardness Bhn
Al-4.5% Cu with grain refiners	no vibration	0.22	23,800	—	2.2	4.3	61
	20 kc, 110 watts	0.14	26,800	—	3.1	5.4	63
Al-4.5% Cu without grain refiners	no vibration	2.4	19,400	—	2.9	5.4	36
	60 c, 3.5 G's, 0.046 cm	1.2	21,500	—	3.1	6.8	41
	20 kc, 110 watts	1.0	26,400	24,600	4.4	9.0	43
Yellow Brass	no vibration	2.2	31,100	12,900	43	43	46
	60 c, 3.5 G's, 0.048 cm	0.11	38,800	15,900	43	40	52
High Strength Yellow Brass	no vibration	0.13	122,500	96,900	18.0	23.5	235
	60 c, 3.5 G's, 0.048 cm	0.14	123,300	98,300	19.4	24.0	239

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TABLE 2

Additions to Copper and Appearance of Resulting Macrostructure

Addition	Concentration Wgt. %	Function	Macrostructure	Average Dia. (mm)	Grain Diameter Length (mm)
Co (pwd)	0.85	Inoculant	Fine Equiaxed	0.25	—
Co (pwd)	0.77	"	" "	0.25	—
FE (pwd)	0.02	"	" "	0.25	—
W (pwd)	0.01	"	" "	0.25	—
Intermetallic Compounds*		Inoculant	Columnar	3.0	30
Bi	0.50	Constitutional Supercool	Equiaxed	0.360	—
Bi	2.60	" "	"	0.30	—
Li	0.02	" "	Fine Equiaxed	0.20	—
Li	0.05	" "	" "	0.250	—
Li	0.07	" "	" "	0.200	—
Li+Bi	0.05+0.50	" "	" "	0.180	—
Li+Bi+Sb	0.05+0.50+0.50	" "	" "	0.180	—
Pb	1.00	" "	Columnar	3.0	30
Ca	1.20	" "	"	3.0	30
Mg	0.50	" "	"	3.0	30
Fe	2.42	Peritectic	Fine Equiaxed	0.13	—
Fe	1.32	Constitutional Supercool	Columnar	3.0	30
Fe	0.02	" "	"	3.0	30
Co	0.96	" "	"	3.0	30
Se	0.50	Adsorption	"	2.0	20
Te	0.50	"	"	2.0	20
Se+Li	0.50+0.02	Adsorption+Const. Supercool	"	3.0	30

* 0.50 wgt. % of the following intermetallic compounds resulted in columnar macrostructures: AlCo, AlFe, AlNi, Co_2Pb, Co_2Sn, CaSi, $PbCe_3$, $PbLa_3$, $SnLa_3$ Mg_3Sb_2, Mg_2Si, SbNi, Sn_3Ni, TiC, TiCo, $TiFe_2$, and $TiNi_3$.

TABLE 3

Effect of Additions on Mechanical and Electrical Properties of As-Cast Copper (Room Temperature Properties)

Addition	Tensile Strength lbs./in²	Elongation per cent	El. Conductivity per cent*
None	28,000	23.8	89.9
0.05% Li	32,000	26.2	37.8
0.05% Li + 0.5% Bi	31,300	30.0	—
0.05% Li + 0.5% Bi + 0.5% Sb	33,600	36.5	35.6

* Standard High Conductivity Copper Bar of U. S. Bureau of Standards = 100%.

der conditions leading to partial or total dissolution in the melt. Table 2 lists all the additions made to copper, shows their amounts, and describes their function and effect on the as-cast grain.

Of all the inoculants only the iron and tungsten powders refined the as-cast structure. To avoid their dissolution in the melt, the superheat was reduced to 2100°F and the pouring temperature at 2030°F. This assured a shallow temperature gradient in the melt. This lowering of superheat and pouring temperature didn't, in itself, exert a grain refining effect. Uninoculated castings, cast under the same conditions, were still totally columnar.

Growth Inhibiting Effect

The double addition method did not produce compound nuclei because the desired compounds either were not formed or were not effective.

The fact that inoculation alone in the presence of a shallow temperature gradient produced a very fine as-cast grain, suggests a growth inhibiting effect exerted by the residual impurities through constitutional supercooling.

Small amounts of bismuth and lithium added separately or together were particularly effective in promoting a fine equiaxed grain structure. On the other hand, calcium and magnesium as additives produced considerably less constitutional supercooling and apparently insufficient to promote independent nucleation in the impurity particles in the melt. Lead additions to copper were generally unsuccessful in grain refining.

In the absence of suitable inoculants additions of less than the amount required to undergo peritectic reaction did not produce grain refinement.

Table 3 shows data demonstrating the improvement in strength and elongation that accompanied the refinement of grain structure by Bi and/or Li.

This investigation used AISI 1020 steel as the base metal. Inoculants were chosen on the basis of stability; grain growth inhibitors were selected for their capability to produce considerable constitutional supercooling.

The inoculants all had cubic crystal structure and included the compounds TiC, ZrC, AlNi, AlCo, and W powders. From extrapolated solidus and liquidus curves, it appeared that Nb, Ti, B, Zr and Si would produce a small solute distribution coefficient when added to iron.

(Continued on page 66)

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These solute additions as well as the inoculants were introduced into melt by a plunger. Additions of each ranged from 0.1 to 1.0 per cent. Inoculating additions were made both alone and in conjunction with grain growth inhibitors.

The steel was melted in a clay-graphite crucible inserted into a high-frequency induction furnace. Superheating temperature was held as closely as possible to 3050°F and the pouring temperature to 2980°F. Melt was deoxidized with aluminum prior to making additions for grain size control.

Inhibitors Plunged First

Grain growth inhibitors were always plunged first to assist in their solution while inoculants were added immediately before pouring in order to minimize the possibility of dissolution. Mold was a cast iron cylinder, 5 in. in diameter and 8 in. high placed on a heavy steel plate to consistently produce a totally columnar structure in the standard base casting.

TiC and ZrC are the only inoculants effective in producing a fine as-cast grain. The degree of refinement is about the same with both additions.

When 0.5 per cent solute addition is used as a common basis for comparison, the grain growth inhibitors can be rated in the following order of decreasing effectiveness: Ti, Nb, Zr, B and Si. This is not the sequence anticipated from the distribution coefficients as determined from extrapolated phase diagrams with iron.

Reduction in the size of the as-cast grain was obtained with additions of Nb to the steel melt.

Mechanical properties were determined for a series of castings containing small amount of Ti and TiC. The specimens were austenitized at 1650°F, quenched in water and tempered at 350°F prior to tensile testing at room temperature. Increasing the TiC content from 0.1 to 0.5 per cent raised the tensile strength continuously, while simultaneous additions of Ti appeared to have a beneficial effect on strength up to about 0.3 per cent.

Increase in strength of 40 per cent over that of the standard was obtained with 0.1 per cent Ti and 0.5 per cent TiC. Unfortunately, this increase in strength was invariably accompanied by a loss of ductility and toughness because of grain boundary precipitation.

The function of the inoculants added to gray iron is to nucleate the graphitic phase of the eutectic. Since the primary graphite in hypereutectic irons will serve this purpose, inoculation additions are only effective or necessary when made by hypoeutectic irons.

Inoculants' Effects Vary

The primary austenite phase does not appear to be capable of nucleating the eutectic graphite, shown by the anomalous nature of this eutectic.[3]

The inoculants known to be effective in controlling graphite structure are numerous.[4] Their effectiveness, however, varies with thermal conditions and composition. Solid graphite, ferrosilicon containing appreciable amounts of aluminum and calcium, calcium-silicon, and special alloy combinations have successfully been employed for this purpose.

Silicon is not effective alone, but improves the effectiveness of some inoculants, such as aluminum, when added with these inoculants. The actual nucleating agents are not known, but may be various metal carbides.

Type A graphite generally exhibits considerably better mechanical properties for most purposes than Type D. Since Type A is favored by inoculation, inoculated irons of 4.1 per cent or lower carbon equivalent are generally of higher quality. One undesirable effect of inoculation, however, is an increase in shrinkage, which requires heavier risering to avoid shrinkage defects.

The hypoeutectic base iron was melted in a hot-blast, acid-lined cupola. The metal was transferred from the cupola to the holding ladle and tapped into smaller pouring ladles from which various castings were poured. Inoculants of the composition listed in Table 4 were added in different amounts to the stream when the ladles were filled.

The castings were 1.2-in. diameter by 12 in. long test bars poured in baked core sand; 2 in. x 2 in. x 12 in. square bars poured either in green or in baked core sand; and 1¼ in. thick chill test bars cast on a thick steel plate. The bars were all risered adequately to assure soundness.

The round bars were tested to determine the effect of various types of inoculation on the macrostructure, tensile and hardness properties. Volumes and weights of the square bars were measured to evaluate the influence of inoculation on mold wall movement and cavity enlargement. Metal superheat and pouring temperatures were controlled as closely as feasible to avoid any side effects.

Silicon up to 0.60 per cent as

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TABLE 4

Additions Made to Hypoeutectic Gray Iron

Type of Addition	Composition			
	% Si	% Al	% Ca	% Fe
Pure Silicon	98.95	0.09	0.01	0.54
Ferro-Silicon	84.60	1.80	0.30	rem.
Pure Alum.	—	99.99	0.001	—

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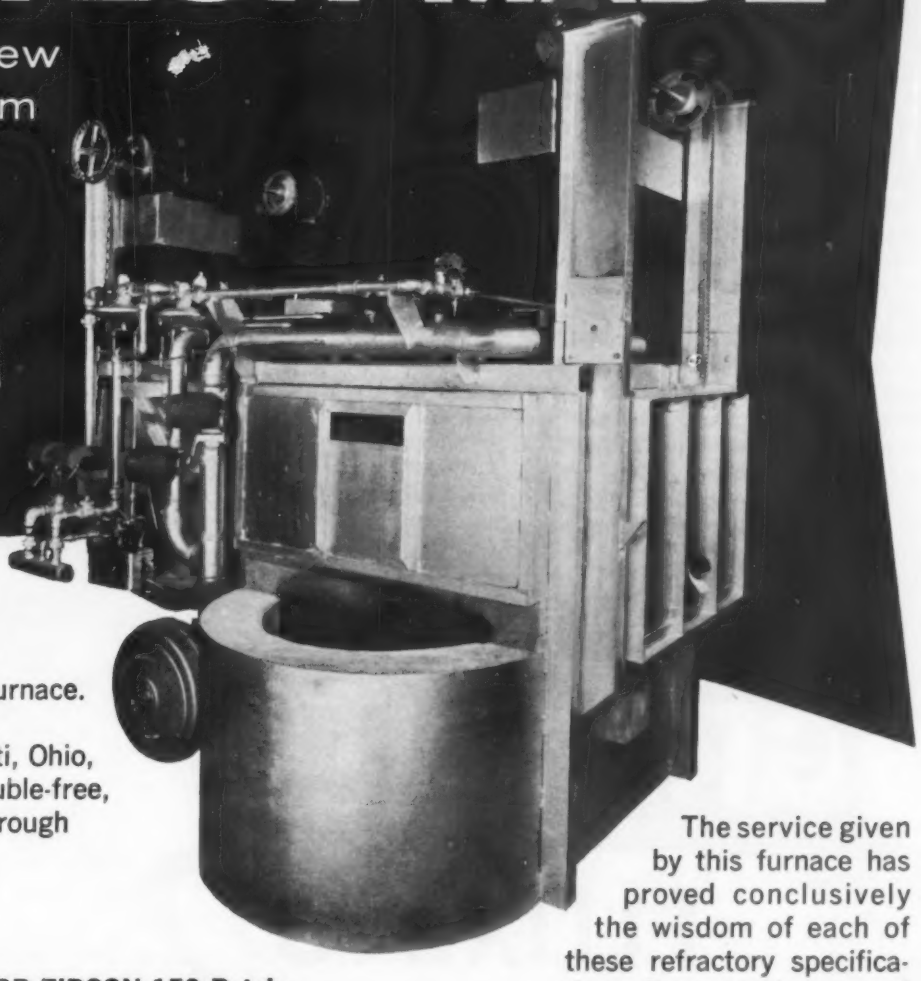

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either pure silicon or ferro-silicon was added to a base iron with 3.10 per cent C and 0.25 per cent Si. Also, the influence of 0.50 per cent silicon on the macrostructure and physical properties was observed. The additives were either pure silicon or ferro-silicon, with various pure aluminum additions to yield a 4.0 per cent carbon equivalent iron.

Increasing amounts of inoculants as ferro-silicon with appreciable amounts of calcium and/or aluminum, reduced the cell size significantly. Pure silicon, on the other hand, does not influence cell size. Effective inoculation delivers an increase in tensile strength and hardness. Pure silicon slightly lowers strength and hardness, presumably because it raises the carbon equivalence and amount of graphite.

Generally, the green sand castings exhibited greater riser shrinkage and therefore necessitated more feed metal than the core sand castings. Moreover, inoculation increased the shrinkage considerably in green sand but only slightly, if at all, in dry sand. The deeper cavity in the green sand riser must be attributed to the greater mold wall movement.[5]

Mold wall movement is dependent both on the state of inoculation and on the rigidity of the sand mold. Aluminum additions with ferro-silicon are effective inoculants and sharply increase volume and weight of castings poured in green sand molds.

Variation in mold wall movement can be rationalized on the basis of the effect exerted by inoculation on the mode of solidification. Ease of graphite nucleation, as produced by appropriate additions, decreases the amount of undercooling, so that solidification begins sooner. As a result the thermal gradient in the liquid is reduced and the depth of partial eutectic freezing or mushy zone increased.

In inoculated casting the pressure is augmented by smaller eutectic cells with their larger total surface area which trap larger quantities of liquid, particularly during the late period of freezing. Graphitization in this entrapped liquid — because of the low density of graphite— exerts a pressure through the expelled liquid iron on the already solidified cells.

This pressure is relieved by movement of the mold wall. In dry sand castings, however, because of the comparatively rigid mold, the movement of the mold wall is slight and the pressure produced by entrapped liquid is relieved by exudation from the riser.

This process of liquid entrapment and pressure exertion occurs continuously along the advancing solid-liquid interface. Soon after the solid skin is formed on the surface of the casting, internal pressure may be relieved by plastic movement of the skin. However, as the solid liquid interface gets further from the mold wall, the skin becomes thick, and the opportunity for such pressure relief becomes increasingly difficult.

The theory of solidification can, in principle, account for most of the important aspects of as-cast structures. It can be employed, at least in a qualitative way, as a guide in establishing the condition necessary for obtaining a desired grain size.

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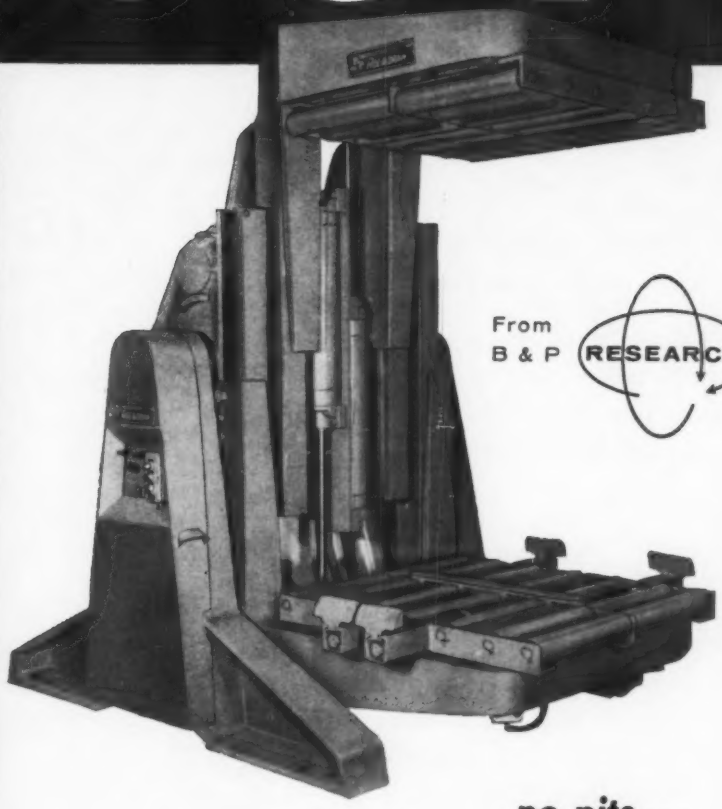

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Malleable iron technology is advanced with a working knowledge of graphite formation during solidification. The principles of formulation describe the conditions under which the various types of graphite must form and explain why mixed types are found in some compositions. 117

About The New Technology

Here are 64 more pages of New Technology — selected breakthroughs in the metalcasting field which appear exclusively in MODERN CASTINGS in 1961.

Interpretive summaries of all New Technology for 1961 appeared in the May issue (pages 69 to 84). The articles are published for the first time since their presentation in San Francisco at the 65th Castings Congress.

These breakthroughs are the most important new technological advances in metalcasting. They were authenticated as new contributions by a 600-man technological committee guided by a member of the editorial and professional staff, S. C. Massari, AFS Technical Director. The section is edited by M. C. Hansen.

All New Technology is further evaluated by MODERN CASTINGS editors for their significance as practical tools today.

POROSITY IN ZINC DIE CASTINGS

by G. P. Lewis, D. A. Craw and R. C. Bell

ABSTRACT

Laboratory methods have been used to study the nature of porosity in commercial zinc die castings. The techniques employed involve primarily density and gas content determinations and gas analysis. By relating the results of these measurements to conditions in the die cavity at the time of solidification it is possible to obtain information on the sources of porosity in the casting tested.

The approach described provides a means of differentiating in a quantitative way between the effects of shrinkage and entrapped gas. It also provides information on the origin of the gas and its final distribution in the casting.

The results were obtained using these techniques on a number of commercial die castings are described. Included are tests designed to examine the effects of lubrication and injection pressure on the porosity of the casting.

INTRODUCTION

The subject of casting porosity is of vital interest to every die caster. Because of the nature of the casting process, pressure die castings contain a relatively high degree of porosity as compared to products of most other casting and fabrication techniques. With proper die design and casting conditions the porosity level is controlled and the porosity is essentially interior; in such cases it is usually of no consequence or concern. If, however, because of faulty or unsuitable die design or improper operating conditions the level of porosity is exceedingly high or the pores extend to the surface layers, then failure or deterioration of the casting in service can result.

Gross porosity, for example, can lead to mechanical failure of the casting under stress. In some instances a degree of pressure tightness is required in the finished part and if the level of porosity is excessive the casting may not meet this requirement. The most frequent problem caused by porosity, however, is concerned with the occurrence of pores in the surface layers of castings which are to be buffed and plated. In such cases the porosity can lead to defects in the electroplated coatings and consequent inferior corrosion resistance in the finished part. Thus, in his efforts to produce consistently high quality die castings, the die caster is constantly concerned with porosity.

Barton,[1] Ruttewit[2] and other workers have considered the way in which die design and operating variables affect the occurrence of porosity from different sources on the basis of practical die casting experience and the existing theories of metal flow during the injection and filling of die cavities. Sachs[3] approached the problem using the laws of mechanics, hydro and thermodynamics, and developed a mathematical expression for the amount of trapped air in a die casting based on the characteristics of the casting machine and the cavity geometry.

In the present work an attempt has been made to determine the sources of porosity in commecial die castings by making laboratory measurements on the castings themselves. The techniques developed have been used to study the porosity in a number of different castings produced in commercial die casting plants using a variety of casting conditions.

LABORATORY METHODS FOR POROSITY STUDY

A measurement of the level of porosity in a die casting can be readily made by a simple density determination. By comparing the density of the casting or a section of the casting with the theoretical density of the alloy the actual volume of voids can be calculated. The amount of gas in the voids can be determined by melting the casting under vacuum and measuring the gas released. Any gas dissolved in the alloy and released during vacuum melting will be included in this measurement, however, as will be shown later, in the case of zinc alloy castings this contribution is negligible. Information on the origin of the gas can be obtained by analysis.

The data obtained from the above measurements can be used to deduce the conditions existing in the die cavity at the time the alloy solidified. The volume this gas would occupy under the conditions of temperature and pressure in the die cavity just prior to solidification is compared with the volume of voids existing just after solidification.

The latter figure is calculated from density considerations making allowance for the contraction of the casting during cooling to room temperature. The difference between the volume of gas and the volume of voids represents solidification shrinkage. Since some of the solidification shrinkage is taken up by flow of metal into the die during solidification, the difference between the volume of voids and gas has been described as unfed solidification shrinkage.

A vital factor in these calculations and one that is difficult to estimate is the pressure existing on the molten alloy at the time of solidification. In recent work carried out in Japan,[4] the variations in metal pressure during the filling of the die have been measured. It has been found that pronounced variations in pressure occur each time the momentum of the injected metal changes, as for example when the cavity or one section of it becomes filled. The completion of the cavity filling results in a pronounced pressure peak whose magnitude is dependent on the cavity design and the applied pressure.

It has been postulated[1] and confirmed,[4] that asso-

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ciated with this pressure peak is an accession of heat to the extent that the solidified skin of the casting may be remelted. The pressure falls away rapidly from the peak value and reaches a steady value apparently corresponding to the applied pressure at the plunger. This is the value that is desired for the calculation of gas volume, since it describes the condition of the gas just prior to solidification of the bulk of the injected alloy. This figure can be deduced from a knowledge of the pressure applied at the plunger or by measuring the pressure of gas in voids located so that no unfed shrinkage would exist, as for example in a blind runner.

EXPERIMENTAL PROCEDURE

The casting to be examined was first cut into convenient-sized sections for density and gas determinations. These samples generally weighed between 50 and 200 grams. Certain sections were taken for metallographic examination.

Density Measurement

The density of the casting sections was determined by the buoyancy method in which the loss in weight of the sample when suspended in distilled water was used to calculate its volume. Corrections were made to reduce weighings to vacuo, to allow for the volume of water displaced by the suspension wire and to adjust for the absolute density of water at the temperature of measurement.

Gas Content and Composition Determination

The gas content was determined by a vacuum fusion technique. The volume of gas released was measured by observing the pressure of this gas in a system of known volume at a measured temperature.

The gas composition was determined by mass spectrometric analysis of small samples sent to the National Research Council of Canada. These samples, ranging in volume from 0.05 to 2 cc (STP), were contained in 50 cc sealed flasks equipped with a break-seal.

Calculations

The density at 20 C (68 F) of die casting alloy containing 4.0 per cent aluminum has been reported as 6.70[5] and 6.6[6] g/cc. Cast samples which were essentially void-free, and whose compositions were determined, were prepared in the laboratory using carefully controlled freezing conditions. The highest density obtained for the 4.0 per cent alloy approached 6.70 g/cc, and this figure was taken as the true density.

The coefficient of linear expansion for the alloy has been reported as 37.1×10^{-6} per degree centrigade for the range 20 C (68 F) to the melting point. If the measured density of the sample at 20 C (68 F) is d, then the volume of voids, V_v, in cc/100 g at the solidus temperature, 380 C (716 F), is

$$100\left(\frac{1}{d}-\frac{1}{6.70}\right)\left[1+(3\times 37.1\times 10^{-6}\times 360)\right]$$

or

$$V_v=\frac{104.01}{d}-15.52$$

In calculating the volume of gas present at the solidification temperature V_g, it is assumed that the oxygen content of the trapped air was present at the time of solidification. However, since no molecular oxygen was found in the gas recovered by vacuum fusion, the appropriate correction to the measured gas has to be made.

If the measured gas content is called S cc/100 g at 0 C and 760 mm pressure (STP), and the measured or estimated nitrogen content is C volume per cent, then the volume of trapped gas at STP is

$$S+\left(\frac{21}{78}\right)\left(\frac{C}{100}\right)S=S\,(1+0.00269\,C)$$

The analyses of a number of samples of gas collected from castings showed that the percentage nitrogen varied from 73.5 to 88.8 and averaged about 85. A value for C of 85 was used in the calculations, and it will be found that variations from this value within the range quoted introduce only a small error (< 3 per cent) in the calculated gas volume.

It is assumed that, at the time of solidification, the temperature of the trapped gas in the cavity will approach that of the alloy. Then, converting the volume of gas to conditions just prior to solidification, 380 C (716 F), and pressure P (psi) gives

$$V_g=S\,[1+(0.00269)\,(85)\,]\left(\frac{14.7}{P}\right)\left(\frac{653}{273}\right)$$

$$V_g=43.2\,\frac{S}{P}\,\text{cc}/100\,\text{g}$$

There is a possibility that the oxygen in the trapped air would be completely reacted at the time of solidification, in view of the turbulence and intimate contact between the gas and metal. If this is so, then no correction for oxygen should be made. This would not affect the values of V_g calculated from pressures obtained from the blind runner measurements described later. However, the values of V_g calculated on the basis of pressure measured at the plunger would be 19 per cent lower if the correction for oxygen is not employed.

The difference between the volume of gas just prior to solidification V_g, and the volume of voids after solidification V_v, is the unfed solidification shrinkage, USS.

$$\text{i.e. } V_v-V_g=\text{USS}$$

The density of liquid alloy at 380 C (816 F) is reported[5] as 6.25 g/cc. The density of solid alloy at the solidus temperature calculated from a density of 20 C (68 F) of 6.70 g/cc and a linear coefficient of expansion of 37.1×10^{-6} is 6.44 g/cc.

The theoretical solidification shrinkage for the alloy is therefore 0.477 cc/100 g or 2.98 volume per cent.

POROSITY NATURE AND DISTRIBUTION IN AN AUTOMOTIVE WINDOW FRAME CASTING

Detailed investigations were carried out on the automotive window frame casting, shown in Fig. 1. The casting consists of a C-shaped frame with a relatively thick rectangular-shaped base. It is fed through two gates—a long thin gate along the side of the frame

about 8½-in. in length by 24-43 mils in thickness and a short thicker gate at the base measuring about 2 in. in length by 50-70 mils in thickness. The weight of the trimmed casting is about 1600 g (3.5 lb).

A total of 19 castings produced in three different dies were examined. All three dies were of essentially the same design, though there were some differences in gate thicknesses. The castings were cut into sections, as shown in Fig. 2, and density and gas determinations made. Section 8M was used for metallographic examinations. Complete results for one casting from each series of samples examined are given in Tables 1 and 2. The gas content of the various sections is plotted in Fig. 3.

Analysis of the castings revealed that the aluminum content was in every case sufficiently close to 4.0 per cent that the effect of variations in the theoretical density of the alloys could be neglected.

To use the density and gas figures to describe conditions in the die at the time of freezing it is necessary to determine the pressure which existed in the cavity after filling but before freezing. This pressure dictates the total volume of the gas bubbles before general freezing commences, and would correspond to the steady pressure reached after the final pressure peak in the experiments reported by Barton and Sakui.[4] If the hydraulic pressure after filling is known then from the ratio of the area of the shot cylinder to that of the metal cylinder, the magnitude of the applied pressure at this point should be calculable.

Failing this information, the pressure could be determined from a section of the casting which was molten after the completion of die filling, and which froze directionally in such a way that virtually no unfed shrinkage resulted. Under these conditions, the volume of the voids after freezing would be equal to the volume of gas before freezing (i.e., USS = 0, therefore: $V_g = V_v$), and the pressure can be calculated using the relationship between V_g and P developed above. In the casting under consideration, it was assumed that the blind runner, marked in Fig. 2, fulfilled these requirements.

A further requirement met by the blind runner was the presence of an appreciable amount of gas so that the effects of any errors in measurement are minor. Densities and gas contents for the blind runners were determined and the pressures calculated. The results are shown in Table 3.

TABLE 1 — DENSITY OF DIE CASTING SECTIONS

Die	A	A	O	B
Casting No.	300b	305c	300f	326a
Weighted Mean	6.45	6.42	6.50	6.54
Position	Density, g/cc			
1	6.65	6.61	6.65	6.63
2	6.63	6.59	6.63	6.61
3	6.62	6.55	6.61	6.61
4	6.45	6.42	6.47	6.49
5	6.32	6.24	6.38	6.41
6	6.42	6.32	6.42	6.44
7	6.40	6.33	6.51	6.53
8	6.24	6.21	6.43	6.47
9	6.29	6.37	6.35	6.54
10	6.44	6.50	6.51	6.64
11	6.53	6.54	6.58	6.66
12	6.53	6.53	6.54	6.61

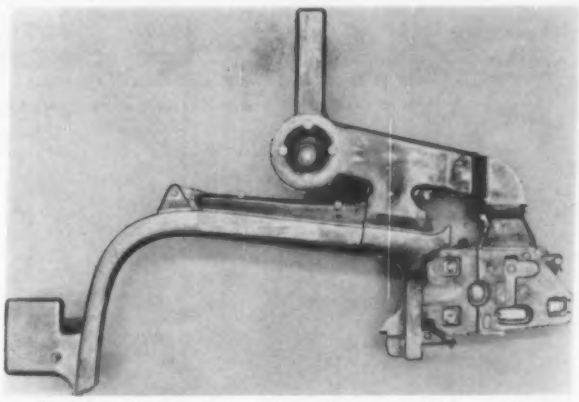


Fig. 1 — Automotive window frame casting used for porosity investigations.

TABLE 2 — GAS CONTENT OF DIE CASTING SECTIONS

Die	A	A	O	B
Casting No.	300b	305c	300f	326a
Weighted Mean	7.51	7.78	6.05	8.49
Position	Gas Content, S, cc/100g (STP)			
1	2.68	3.31	2.56	6.41
2	4.25	4.97	4.43	7.47
3	3.97	4.79	3.85	6.45
4	6.00	6.24	5.48	8.85
5	8.04	9.94	6.94	12.86
6	8.98	10.49	7.77	11.89
7	10.21	10.37	7.25	8.93
8	13.45	12.65	8.97	10.15
9	11.45	8.63	8.73	7.92
10	7.84	n/a*	4.98	3.56
11	7.44	5.75	5.44	4.81
12	5.84	7.17	6.16	8.51

*n/a indicates not available.

TABLE 3 — MEASUREMENTS OF DENSITY AND GAS CONTENTS OF BLIND RUNNERS AND CALCULATED METAL PRESSURE

Die	Casting No.	d, g/cc	S, cc/100g (STP)	V_v (V_g), cc/100g	Pressure, psi
A	300b	6.57	12.30	0.31	1714
A	305c	6.52	11.82	0.43	1187
O	300f	6.53	15.60	0.41	1644
B	326a	6.51	25.05	0.46	2353

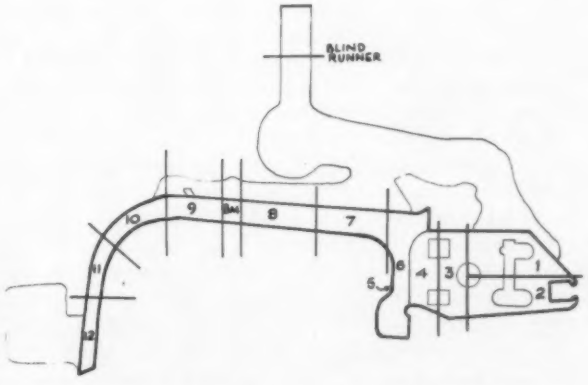


Fig. 2 — Location of sections used for density and gas determinations.

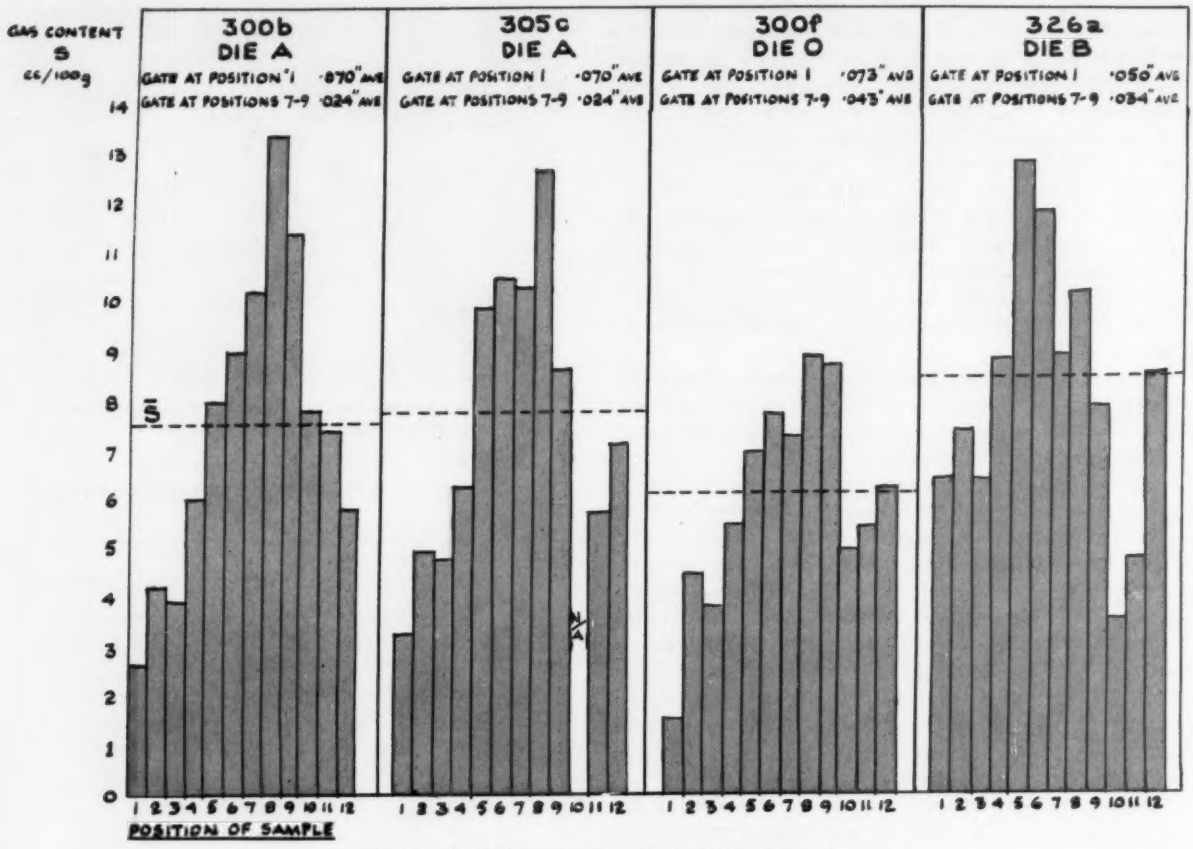

GAS CONTENT
S
cc/100g
300b
DIE A
GATE AT POSITION 1 .070" AVG
GATE AT POSITIONS 7-9 .024" AVG
305c
DIE A
GATE AT POSITION 1 .070" AVG
GATE AT POSITIONS 7-9 .024" AVG
300f
DIE O
GATE AT POSITION 1 .073" AVG
GATE AT POSITIONS 7-9 .043" AVG
326a
DIE B
GATE AT POSITION 1 .050" AVG
GATE AT POSITIONS 7-9 .034" AVG
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
1 2 3 4 5 6 7 8 9 10 11 12
POSITION OF SAMPLE

Fig. 3 — Variation of gas content with position.

Metal Pressure Variations

Wide variations in metal pressure for the different castings are indicated by these calculations. It should be pointed out that the castings were produced on different machines except for the two series from die *A* and in this case there was a lapse of several months between the series. In a given series produced over a short period, the indicated blind runner pressures were quite consistent, varying less than 10 per cent from the average. Consideration of the results of measurements made on the castings themselves reveals that pressure variations of the order indicated in Table 3 did exist and confirms, at least partially, the validity of the assumptions.

It is known that operating factors, such as the accumulator pressure, the amount of gas in the accumulator, the condition of the hydraulic system and of the plunger rings, can have a marked effect on the final pressure applied to the metal.

The above pressures have been used to calculate the volume of voids V_v, volume of gas V_g, and the unfed solidification shrinkage, shown in Table 4. The functions have also been plotted as a histogram (Fig. 4).

Considerable differences in both densities and gas contents exist among the castings produced from the different dies. It will be noted, however, that the general pattern of density and gas variations is similar for all castings, with the sections in the middle portion (Positions 4-9) being generally lower in density and higher in gas content than the remainder of the casting (Positions 1-3 and 10-12).

The gas content of the various sections of the castings provides an indication of the flow pattern of the metal in filling the cavity, and of the manner in which the air present in the cavity is moved by the incoming metal. Because of the location of the two gates, it would be expected that the gas content would be high at a point between them where the two inflowing streams of metal meet. This has in fact occurred (Fig. 3). It is interesting to note further that in the case of the castings produced in dies *A* and *O* the highest gas content occurs at position 8, while in the casting produced in die *B* it occurs at position 5.

As noted in Fig. 3, it was found that the average thickness of the gate at position one in die *B* was 50 mils, whereas in dies *A* and *O* the average thickness of this gate was about 70 mils. The gate at positions 7-9 on die *B* was intermediate in thickness between that on dies *A* and *O*. It would appear that, within limits, the size of the gate at position one would have the greater effect in determining the meeting point of the streams from the two gates, and that the variation noted is the reason for the difference in gas distribution.

Shrinkage vs. Porosity

An outstanding point revealed by the calculated values for V_v, V_g and USS (Table 4 and Fig. 4) is the large contribution of shrinkage to the porosity level. For every casting the unfed shrinkage makes up over 50 per cent of the volume of voids when averaged

TABLE 4 — CALCULATED VALUES FOR V_v, V_g, AND USS

Die	Casting No.	Position	d, g/cc	S, cc/100g (STP)	V_v, cc/100g	V_g, cc/100g	$\frac{V_g}{V_v}$, %	USS, cc/100g	USS, % of Theoretical
A	300b	1	6.65	2.68	0.12	0.07	58.3	0.05	10.5
		2	6.63	4.25	0.17	0.11	64.7	0.06	12.6
		3	6.62	3.97	0.19	0.10	52.6	0.09	18.7
		4	6.45	6.00	0.60	0.15	25.0	0.45	94.3
		5	6.32	8.04	0.94	0.20	21.3	0.74	155.1
		6	6.42	8.98	0.68	0.23	33.8	0.45	94.3
		7	6.40	10.21	0.73	0.26	35.6	0.47	98.5
		8	6.24	13.45	1.15	0.34	29.6	0.81	169.8
		9	6.29	11.45	1.02	0.29	28.4	0.73	153.0
		10	6.44	7.84	0.63	0.20	31.7	0.43	90.1
		11	6.53	7.44	0.41	0.19	46.3	0.22	46.1
		12	6.53	5.84	0.41	0.15	36.6	0.26	54.5
Weighted Mean			6.47	7.52	0.56	0.19	33.9	0.37	77.6
A	305c	1	6.61	3.31	0.22	0.12	54.5	0.10	21.0
		2	6.59	4.97	0.26	0.18	69.2	0.08	16.8
		3	6.55	4.79	0.36	0.17	47.2	0.19	39.8
		4	6.42	6.24	0.68	0.23	33.8	0.45	94.3
		5	6.24	9.94	1.15	0.36	31.3	0.79	165.6
		6	6.32	10.49	0.94	0.38	40.4	0.56	117.4
		7	6.33	10.37	0.91	0.38	41.8	0.53	111.1
		8	6.21	12.65	1.23	0.46	37.4	0.77	161.4
		9	6.37	8.63	0.81	0.31	38.3	0.50	104.8
		10	6.50	n/a*	0.48	—	—	—	—
		11	6.54	5.75	0.38	0.21	55.3	0.17	35.6
		12	6.53	7.17	0.41	0.26	63.4	0.15	31.4
Weighted Mean			6.42	7.78	0.68	0.28	41.2	0.40	83.9

(continued in next column)

TABLE 4 — CALCULATED VALUES FOR V_v, V_g, AND USS *(continued)*

Die	Casting No.	Position	d, g/cc	S, cc/100g (STP)	V_v, cc/100g	V_g, cc/100g	$\frac{V_g}{V_v}$, %	USS, cc/100g	USS, % of Theoretical
O	300f	1	6.65	2.56	0.12	0.07	58.3	0.05	10.5
		2	6.63	4.43	0.17	0.12	70.6	0.05	10.5
		3	6.61	3.85	0.22	0.10	45.5	0.12	25.2
		4	6.47	5.48	0.56	0.14	25.0	0.42	88.0
		5	6.38	6.94	0.78	0.18	23.1	0.60	125.8
		6	6.42	7.77	0.68	0.20	29.4	0.48	100.6
		7	6.51	7.25	0.46	0.19	41.3	0.27	56.6
		8	6.43	8.97	0.66	0.24	36.4	0.42	88.0
		9	6.35	8.73	0.86	0.23	26.7	0.63	132.1
		10	6.51	4.98	0.46	0.13	28.3	0.33	69.2
		11	6.58	5.44	0.29	0.14	48.3	0.15	31.4
		12	6.54	6.16	0.38	0.16	42.1	0.22	46.1
Weighted Mean			6.50	6.09	0.48	0.16	33.3	0.32	67.1
B	326a	1	6.63	6.41	0.17	0.12	70.6	0.05	10.5
		2	6.61	7.47	0.22	0.14	63.6	0.08	16.8
		3	6.61	6.45	0.22	0.12	54.5	0.10	21.0
		4	6.49	8.85	0.51	0.16	31.4	0.35	73.4
		5	6.41	12.86	0.71	0.24	33.8	0.47	98.5
		6	6.44	11.89	0.63	0.22	34.9	0.41	86.0
		7	6.53	8.93	0.41	0.16	39.0	0.25	52.4
		8	6.47	10.15	0.56	0.19	33.9	0.37	77.6
		9	6.54	7.92	0.38	0.15	39.5	0.23	48.2
		10	6.64	3.56	0.14	0.07	50.0	0.07	14.7
		11	6.66	4.81	0.10	0.09	90.0	0.01	2.1
		12	6.61	8.51	0.22	0.16	72.7	0.06	12.6
Weighted Mean			6.54	8.50	0.38	0.16	42.1	0.22	46.1

*n/a indicates not available

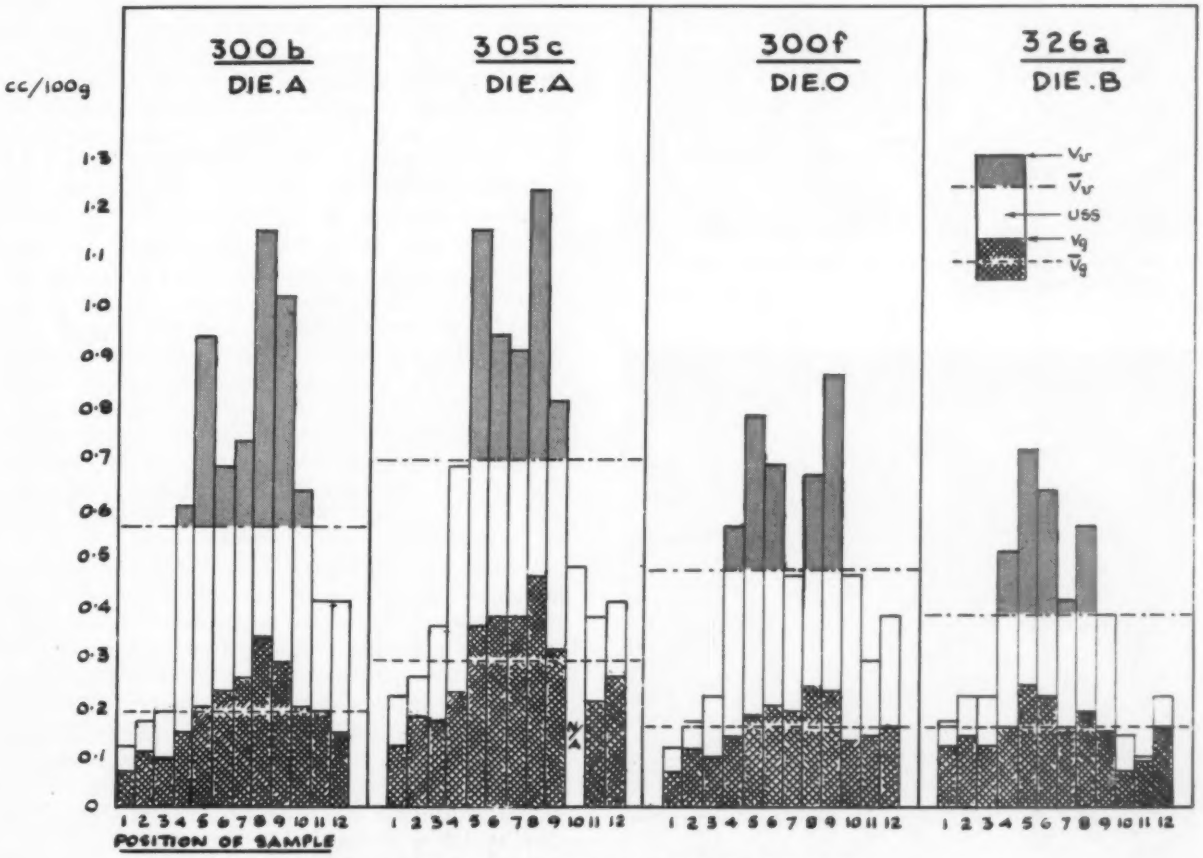


Fig. 4 — Variation of functions V_v, V_g and USS with position.

over all sections. In sections of high porosity (density between 6.2 and 6.3) shrinkage contributes between 60 and 70 per cent of the total volume of the voids. In these cases the calculated shrinkage is considerably greater than the theoretical solidification shrinkage for the alloy.

This is interpreted as indicating that these regions froze late in the solidification cycle, and that molten metal moved from them to adjacent regions to compensate for shrinkage. The generally high level of shrinkage found in castings 300b, 305c and 300f indicates that the gates froze quite early in the cycle preventing access of molten metal under pressure during most of the freezing period.

The two castings from die *A* show similar gas contents, indicating similar flow patterns in the die as might be expected. There was, however, an appreciable difference in applied pressure, as shown in Table 3, and this would result in a greater volume of gas (V_g) in 305c at the time of freezing. The extent of unfed shrinkage was apparently the same in the two castings; thus the difference in gas volume has given rise to a slightly lower density in casting 305c.

The casting from die *O* (300f) shows an improvement from the point of view of overall porosity on these from die *A*. The indicated pressure on the melt after filling was similar to that of casting 300b; however, the gas content was lower, and therefore the gas volume was less. The amount of unfed shrinkage was also lower. It will be noted that the greatest difference in gas content occurred in sections 7-12 of the castings, particularly near the gate. As noted in Fig. 3, the gate thickness was appreciably greater in the case of die *O*, and this may well have led to reduced turbulence and less entrapment of gas in this region.

Casting 326a, which was produced in die *B*, showed a still lower porosity level than the other castings (Fig. 4). While the overall gas content was a little higher than that of the other castings (Fig. 3), its calculated volume was somewhat lower because of the higher indicated pressure. The unfed solidification shrinkage was appreciably lower, and these two factors together accounted for the decreased porosity level in the solidified casting.

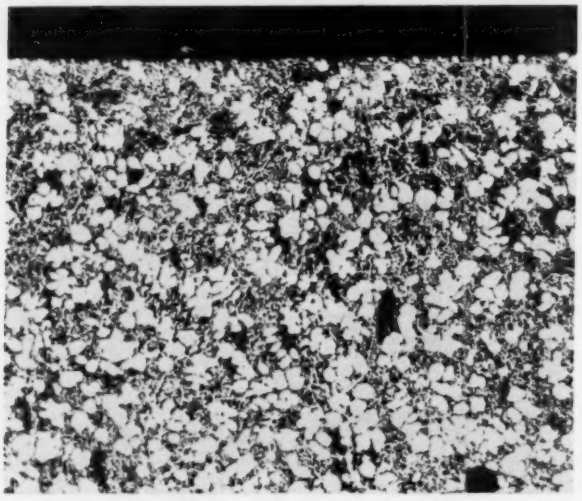


Fig. 5 — Surface structure at position 8M on casting 300b. 250 ×.

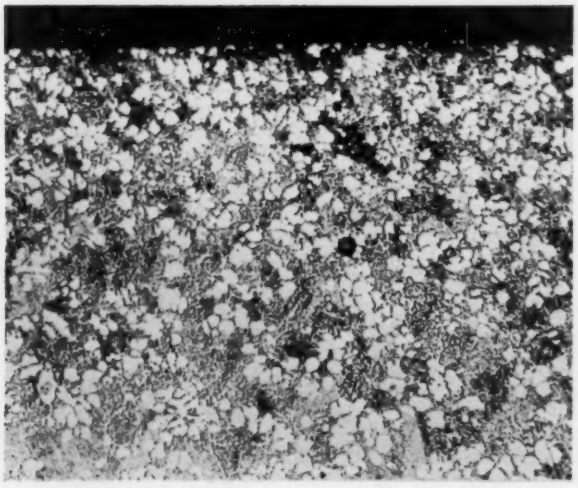


Fig. 6 — Surface structure at position 8M on casting 305c. 250 ×.

Die Thermal Conditions

The porosity and other characteristics of the castings are also affected by the thermal conditions existing in the die during filling and solidification. Some information of a qualitative nature on these conditions can be obtained from a metallographic examination of the casting structures. Since the surface structures vary in nature from place to place on a given casting, it is necessary when comparing a number of castings to examine structures at identical locations. Figures 5 to 8 illustrate comparative structures on the castings under consideration. The fields shown are located at the ejector die surface at identical points on section 8 M.

Castings 300b, 305c and 300f show similar structures indicating that the thermal conditions, at least at the location considered, were also similar. The surface structure observed in casting 326a was however distinctly different from that found in the other castings. Over much of the surface, which was adjacent to the ejector die at the position examined, a pronounced growth of columnar dendrites existed, as shown in Fig. 8. It has been observed that, in die castings, this type of structure often occurs at surface areas where a high heat extraction rate during freezing might be expected, as at a convex surface.

In the case of casting 326a then, this structure may represent more rapid freezing rates, possibly due to lower die temperatures or more effective cooling, as compared to those existing in the other dies. The difference in thermal conditions indicated may have contributed to the lower porosity levels.

An important consideration in the study of porosity is its distribution between the surface layers and the interior of the casting, since this may determine the extent to which it will cause detrimental effects. This distribution was readily obtained from examination of the metallographic sections. In castings 300b, 305c

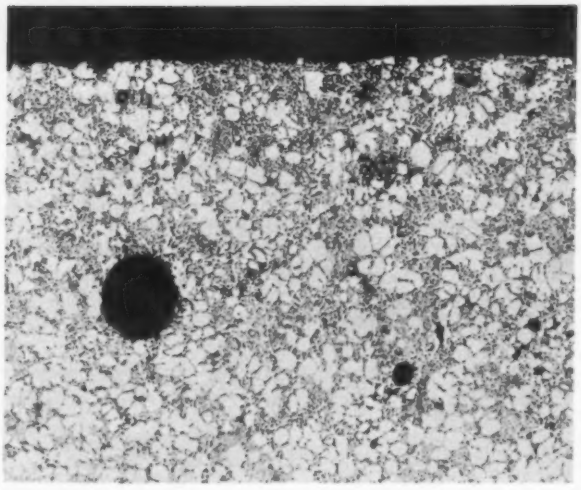


Fig. 8 — Surface structure at position 8M on casting 326a. 250 ×.

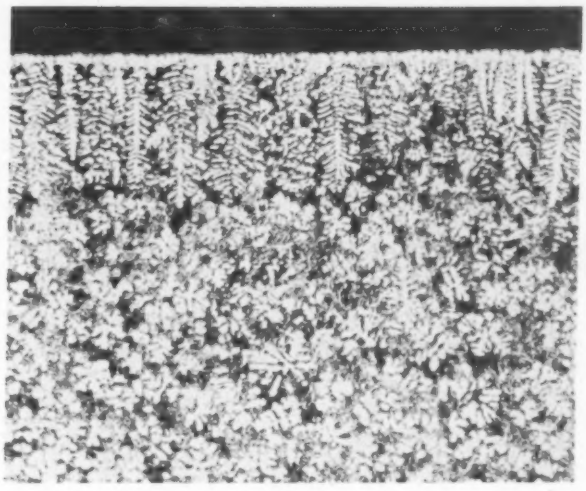


Fig. 7 — Surface structure at position 8M on casting 300d. 250 ×.

TABLE 5 — GAS ANALYSIS

Die	A	A	O	B
Position	9	8	8	8
Sample	300a	305c	300d	326a
Gas Content for sample, cc/100g (STP)	10.41	12.65	9.13	10.15
Gas	Analysis, in volume %			
H_2	13.8	12.3	12.9	25.0
N_2	84.6	86.0	86.0	73.5
Ar	0.96	1.03	1.00	0.86
CO_2	0.18	0.40	—	0.15
CH_4	0.37	0.25	0.26	0.40

and 300f pores extended close to the surface layers (within 5 mils of the surface), while in casting 326a the surface layers were relatively free from porosity. This suggested that surface porosity was not directly related to the general porosity level but rather to thermal conditions existing in the cavity. This is supported by the observation that low densities result mainly from high levels of unfed shrinkage, which would be expected to affect mainly the center of the casting.

GAS COMPOSITION

To investigate the source of the gas present in commercial die castings, detailed analyses of gas samples taken from a number of die castings and samples of die casting alloy were carried out. The analysis was done on a mass spectrometer by the National Research Council of Canada. Typical results from the die casting samples are given in Table 5. The gas samples were taken from sections of the castings, and the gas content of the section used in each case is tabulated. The analyses of gas samples from castings 300b and 300f were not available, however, castings 300a and 300d quoted in the table were produced at the same time as 300b and 300f, respectively.

The gas sample obtained by vacuum fusion will include, along with the gas released from the pores, gas which was in solution in the alloy. To check the extent of the contribution of dissolved gas, several samples of pore-free cast alloy were melted under vacuum and the amount of gas evolved was measured and analysed. Of the order of 0.4 cc of gas/100 g of alloy (STP) was obtained from these samples, and it analysed approximately 40 per cent hydrogen and 25 per cent nitrogen by volume. The other major constituent of the gas was carbon dioxide, amounting to 30 per cent. Thus, the amount of gas which could originate from solution in the alloy is quite small in comparison with the total gas recovered from the die casting samples.

It will be seen from Table 5 that the principal constituents in the gas taken from the castings are nitrogen and hydrogen. It should be noted however that since carbon monoxide and nitrogen both have a mass of 28, they are not readily distinguishable on the mass spectrometer and are reported together as nitrogen. Since the solubility of nitrogen in the alloy is low, it can be assumed that practically all of the nitrogen present originated from trapped air in the casting. The nitrogen-argon ratio is somewhat greater than the normal 83 : 1 for air and probably the excess nitrogen reported (up to 0.5 cc/100 g) is actually carbon monoxide, possibly originating from lubricant.

The results show a hydrogen content of from 1.2 to 2.5 cc/100 g. According to the findings quoted above, about 0.2 cc/100 g could come from the alloy. It would appear that the remainder must have come from the reduction of water vapor in the entrapped air, or from the breakdown of lubricant in the

TABLE 6 — LUBRICATION EFFECT ON DENSITY AND GAS CONTENT

Die	Casting No.	Lubrication Conditions	Mean Density, Pos. 7-12, g/cc	Density, Pos. 8 g/cc	Gas Content (S), Pos. 8, cc/100g (STP)	Metal Pressure (As indicated by blind runner, psi	V_g, cc/100g
A	305a	No lubricant	6.40	6.26	11.45	1281	0.39
A	305b	No lubricant	6.39	6.28	11.53	1228	0.41
A	305c	Normal spray Water emulsion lubricant (X)	6.39	6.21	12.65	1187	0.46
A	305d	Excessive spray Lubricant (X)	6.38	6.14	15.45	1221	0.55
A	305e	Excessive spray Lubricant (X)	6.40	6.25	13.77	1277	0.47
A	305f	Normal spray Organic solvent lubricant (Y)	6.38	6.21	13.05	1152	0.49
A	305g	Excessive spray Lubricant (Y)	6.36	6.22	13.53	1230	0.48
A	305h	Normal spray Organic solvent lubricant (Z)	6.41	6.30	10.73	1295	0.36
A	305i	Excessive spray Lubricant (Z)	6.39	6.22	12.81	1287	0.43
A	305j	Excessive spray Lubricant (Z)	6.38	6.22	14.57	1235	0.51

die. Calculations show that if the entrapped air were warm and of high humidity, the hydrogen which would be present as water vapor could account for practically all of the rest of the hydrogen found. On the other hand, if the lubricant used were a water-base type this could well be another source of water vapor.

In the event that vaporization was not complete when the die closed it could also lead to increased gas content in the casting. Similarly, it might be expected that organic-based lubricants could contribute hydrogen and lead to increased gas content as well, if their end points were too high.[7] To investigate further the effects of lubrication on porosity and gas content, a separate series of tests was carried out.

Lubricant Tests

The lubricant tests were done on the window frame casting previously described. Differing types and amounts of lubricant were applied to the die, as outlined in Table 6. This table also shows the mean density of the six positions on the frame portion of the casting (position 7-12) and the gas content of position 8 on the castings. The castings were all produced on the same die over a short period of time with other casting conditions kept as constant as possible.

The composition of the gas released from position 8 in each case is shown in Table 7. Taking as a base level the hydrogen content for the nonlubricated castings (1.2 cc/100 g), the increase in hydrogen content for each of the lubricated castings is also shown.

TABLE 7 — LUBRICANT EFFECT ON GAS COMPOSITION

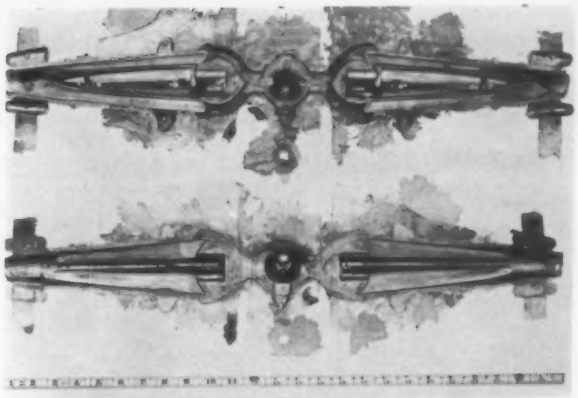
Casting No., Pos. 8	Lubricant	Gas Composition, Volume % H_2	N_2	Ar	CO_2	CH_4	Hydrogen Content, cc/100g (STP)	Increase in Hydrogen Content, cc/100g (STP)
305a	None	10.0	88.8	1.05	—	0.15	1.15	—0.05
305b	None	10.8	87.9	1.03	0.10	0.14	1.25	+0.05
305c	Type X	12.3	86.0	1.03	0.40	0.25	1.56	0.36
305d	Excess Type X	15.2	83.6	0.94	—	0.30	2.35	1.15
305e	Excess Type X	19.1	79.5	0.90	—	0.52	2.63	1.43
305f	Type Y	12.7	86.0	1.02	0.1	0.18	1.66	0.46
305g	Excess Type Y	19.9	78.7	0.84	0.1	0.47	2.69	1.49
305h	Type Z	15.4	83.3	1.08	—	0.22	1.65	0.45
305i	Excess Type Z	15.2	83.6	0.90	—	0.26	1.95	0.75
305j	Excess Type Z	21.8	76.8	0.84	—	0.56	3.18	1.98

The results of this test show, first of all, that the use of lubricants even in excessive amounts had little or no effect on the mean density of the casting. The gas content of position 8 did however increase with the use of normal amounts of lubricant, and an even greater increase resulted from the use of excessive amounts. Gas contents for the other sections of the castings are not available, but it would appear that while an increase was noted in position 8 the change over the whole casting was not sufficient to effect the mean density appreciably. The density of position 8 varied widely but seemed to bear little relationship to the lubricant conditions. This was apparently because of variations in the distribution of unfed shrinkage in the different castings.

Considering the gas composition, a definite increase in the hydrogen content (and also in the methane content) resulted from the use of lubricants. In the case of position 8 this was sufficient to account for an increase in the hydrogen content of up to 1.5 to 2 cc/100 g in instances of excessive amounts of lubricant spray. With normal amounts of spray increases in hydrogen content of the order of 0.4 cc/100 g were found.

Summarizing the findings on gas porosity, it has been found that the gas present in commercial die castings consists principally of nitrogen and hydrogen with minor amounts of argon, carbon dioxide, methane and carbon monoxide also present. The nitrogen has originated from trapped air in the castings; the oxygen associated with the nitrogen has been lost by reaction either during casting or during the melting

Fig. 9 — Automotive ornament casting used for investigation of effects of variations in injection pressure on porosity.



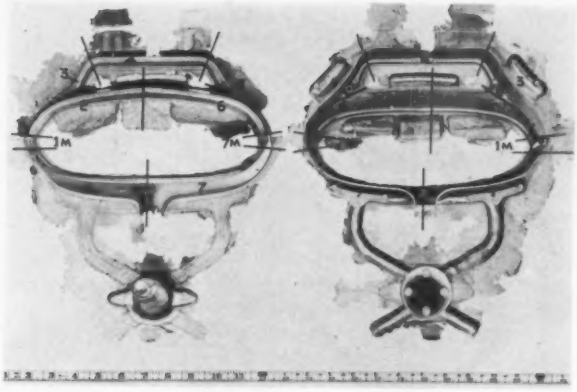


Fig. 10 — Automotive taillight casting used for investigation of effects of variations of injection pressure on porosity. Locations of sections used for density and gas determinations are marked.

procedure for gas recovery. The hydrogen content can be readily accounted for as originating from a combination of sources—dissolved gas in the alloy, water vapor in the trapped air and decomposition of lubricants. The use of lubricant even in excessive quantities had little or no effect on the overall density of the casting, though it did increase the gas content appreciably at some locations.

INJECTION PRESSURE EFFECT ON POROSITY IN AN AUTOMOTIVE TAILLIGHT CASTING

Two further series of tests were carried out to study the effect of injection pressure on the porosity and gas content of die castings. The tests were performed on the automotive ornament casting, shown in Fig. 9, and on the automotive taillight, shown in Fig. 10. Since the results obtained for the two castings were generally similar, only the findings for the taillight casting will be described.

The taillight casting was fed by two gates each of which was 4 in. in length and averaged about 35 mils in thickness. The weight of the trimmed casting was about 500 g (1.1 lb).

The test castings were produced in a single run using seven different pressures. The hydraulic pressure was varied in 100 psi steps from 1200 to 600 psi, corresponding to metal pressures of 2140 to 1070 psi. Six castings were produced at each pressure. After every third shot the die was lubricated. As far as possible, all conditions were kept constant during the test; at the lowest pressure (1070 psi) however, some difficulty was experienced in locking the machine and the casting rate was necessarily cut from three to two/min. Die temperatures were 221-238 C (430-460 F) for the ejection die and 238-249 C (460-480 F) for the cover die. Metal temperature was 418-421 C (785-790 F).

Two castings from each pressure, one before and one after lubrication, were chosen for testing. The castings were cut into nine sections, as shown in Fig. 10. Density determinations were carried out on all sections. However, since the casting was symmetrical in shape, and since density determinations indicated that the two sides were similar, gas determinations were limited to sections 4 to 7 inclusive. These gas determinations were performed on castings from three pressures—2140, 1600 and 1070 psi. For the remainder of the pressure levels, determinations were made on section 7 only.

Density and Gas Determinations

All of the density and gas determinations are shown in Tables 8 and 9 and Fig. 11. These figures have been used to calculate the functions V_v, V_g and USS, which are shown in Table 10 and are also plotted on the histogram (Fig. 12). For these calculations the metal pressure figure determined from the hydraulic pressure measured during casting has been used for the pressure on the liquid alloy in the die cavity before freezing.

While it is recognized that this calculated pressure may be subject to some error due to operational factors, the fact that all of the castings were produced on the same machine over a short period of time should make the results comparative. It should be pointed out also that, as mentioned previously, if the oxygen in the entrapped gas is all reacted prior to the complete filling of the cavity, the calculated values of V_g should be about 19 per cent lower than shown.

In general, the castings were found to be of high density and low gas content compared to other commercial castings which have been examined. The amount of unfed shrinkage was also quite low, amounting to less than 40 per cent of the theoretical solidification shrinkage for the alloy.

TABLE 8 — INJECTION PRESSURE EFFECT ON DENSITY OF TAILLIGHT MOUNT CASTINGS

Nonlubricated Castings							
Casting No.	1200-3	1100-5	1000-5	900-5	800-5	700-5	600-2
Pressure, psi	2140	1960	1780	1600	1420	1250	1070
Weighted Mean	6.59	6.59	6.58	6.56	6.57	6.56	6.56
Position	Density, g/cc						
1	6.61	6.61	6.59	6.58	6.60	6.57	6.58
1M	6.48	6.47	6.45	6.44	6.44	6.41	6.43
2	6.60	6.59	6.58	6.57	6.58	6.56	6.57
3	6.61	6.60	6.59	6.57	6.60	6.56	6.56
4	6.59	6.59	6.59	6.55	6.57	6.56	6.55
5	6.60	6.58	6.58	6.56	6.55	6.57	6.56
6	6.59	6.58	6.58	6.56	6.56	6.56	6.54
7M	6.49	6.45	6.47	6.43	6.43	6.45	6.40
7	6.62	6.61	6.61	6.61	6.60	6.61	6.60
Lubricated Castings							
Casting No.	1200-4	1100-6	1000-6	900-6	800-6	700-6	600-3
Weighted Mean	6.59	6.57	6.57	6.57	6.57	6.56	6.56
Pressure, psi	2140	1960	1780	1600	1420	1250	1070
1	6.61	6.58	6.59	6.57	6.60	6.59	6.58
1M	6.45	6.45	6.46	6.46	6.41	6.41	6.40
2	6.60	6.58	6.58	6.59	6.58	6.57	6.57
3	6.59	6.60	6.60	6.59	6.59	6.57	6.57
4	6.59	6.58	6.58	6.57	6.54	6.52	6.54
5	6.59	6.58	6.58	6.57	6.59	6.58	6.57
6	6.57	6.57	6.56	6.56	6.55	6.57	6.54
7M	6.48	6.43	6.44	6.44	6.44	6.43	6.40
7	6.61	6.60	6.60	6.60	6.59	6.60	6.60

Lowering of the injection pressure resulted in a slight decrease in density in all positions of the casting. The mean density for the complete casting decreased from 6.59 to 6.56 g/cc (or in other words the per cent porosity increased from 1.58 to 2.03) with

TABLE 9 — INJECTION PRESSURE EFFECT OF GAS CONTENTS OF TAILLIGHT MOUNT CASTINGS

Nonlubricated Castings							
Casting No.	1200-3	1100-5	1000-5	900-5	800-5	700-5	600-2
Pressure, psi	2140	1960	1780	1600	1420	1250	1070
Weighted Mean	5.29	—	—	4.88	—	—	4.09
Position	Gas Content (S), cc/100g (STP)						
4	6.49	—	—	5.94	—	—	5.64
5	4.45	—	—	3.96	—	—	3.26
6	6.69	—	—	5.62	—	—	4.48
7M	5.21	—	—	6.04	—	—	5.21
7	4.05	3.73	3.78	3.89	3.47	2.08	3.05
Lubricated Castings							
Casting No.	1200-4	1100-6	1000-6	900-6	800-6	700-6	600-3
Pressure, psi	2140	1960	1780	1600	1420	1250	1070
Weighted Mean	5.65	—	—	5.58	—	—	4.35
Position	Gas Content (S), cc/100g (STP)						
4	7.46	—	—	7.11	—	—	6.92
5	4.68	—	—	5.35	—	—	3.47
6	6.76	—	—	6.32	—	—	4.37
7	4.37	4.16	4.54	4.29	4.73	3.89	3.26

Blank (—) indicates determination not done.

TABLE 10 — INJECTION PRESSURE EFFECT ON THE FUNCTIONS V_v, V_g AND USS

Casting No.	Pressure, psi	V_v, cc/100g	V_g, cc/100g	$\frac{V_g}{V_v}$, %	USS, cc/100g	USS, % of Theoretical
Position 4						
Nonlubricated						
1200-3	2140	0.26	0.13	50.0	0.13	27.2
900-5	1600	0.36	0.16	44.4	0.20	41.9
600-2	1070	0.36	0.23	63.9	0.13	27.3
Lubricated						
1200-4	2140	0.26	0.15	57.7	0.11	23.1
900-6	1600	0.31	0.19	61.3	0.12	25.2
600-3	1070	0.38	0.28	73.7	0.10	21.0
Position 5						
Nonlubricated						
1200-3	2140	0.24	0.09	37.5	0.15	31.4
900-5	1600	0.34	0.11	32.4	0.23	48.2
600-2	1070	0.34	0.13	38.2	0.21	44.0
Lubricated						
1200-4	2140	0.26	0.09	34.6	0.17	35.6
900-6	1600	0.31	0.14	45.2	0.17	35.6
600-3	1070	0.31	0.14	45.2	0.17	35.6
Position 6						
Nonlubricated						
1200-3	2140	0.26	0.14	53.8	0.12	25.2
900-5	1600	0.34	0.15	44.1	0.19	39.8
600-2	1070	0.38	0.18	47.4	0.20	41.9
Lubricated						
1200-4	2140	0.31	0.14	45.2	0.17	35.6
900-6	1600	0.34	0.17	50.0	0.17	35.6
600-3	1070	0.38	0.18	47.4	0.20	41.9
Position 7						
Nonlubricated						
1200-3	2140	0.19	0.08	42.1	0.11	23.1
1100-5	1960	0.22	0.08	36.4	0.14	29.3
1000-5	1780	0.22	0.09	40.9	0.13	27.3
900-5	1600	0.22	0.11	50.0	0.11	23.1
800-5	1420	0.24	0.11	45.8	0.13	27.3
700-5	1250	0.22	0.07	31.8	0.15	31.4
600-2	1070	0.24	0.12	50.0	0.12	25.2
Lubricated						
1200-4	2140	0.22	0.09	40.9	0.13	27.3
1100-6	1960	0.24	0.09	37.5	0.15	31.4
1000-6	1780	0.24	0.11	45.8	0.13	27.3
900-6	1600	0.24	0.12	50.0	0.12	25.2
800-6	1420	0.26	0.14	53.8	0.12	25.2
700-6	1250	0.24	0.13	54.2	0.11	23.1
600-3	1070	0.24	0.13	54.2	0.11	23.1
Position 7M						
Nonlubricated						
1200-3	2140	0.51	0.11	21.6	0.40	83.9
900-5	1600	0.66	0.16	24.2	0.50	104.8
600-2	1070	0.73	0.21	28.8	0.52	109.0
Lubricated						
1200-4	2140	0.53	n/a			
900-6	1500	0.63	n/a			
600-3	1070	0.73	n/a			

n/a indicates not available.

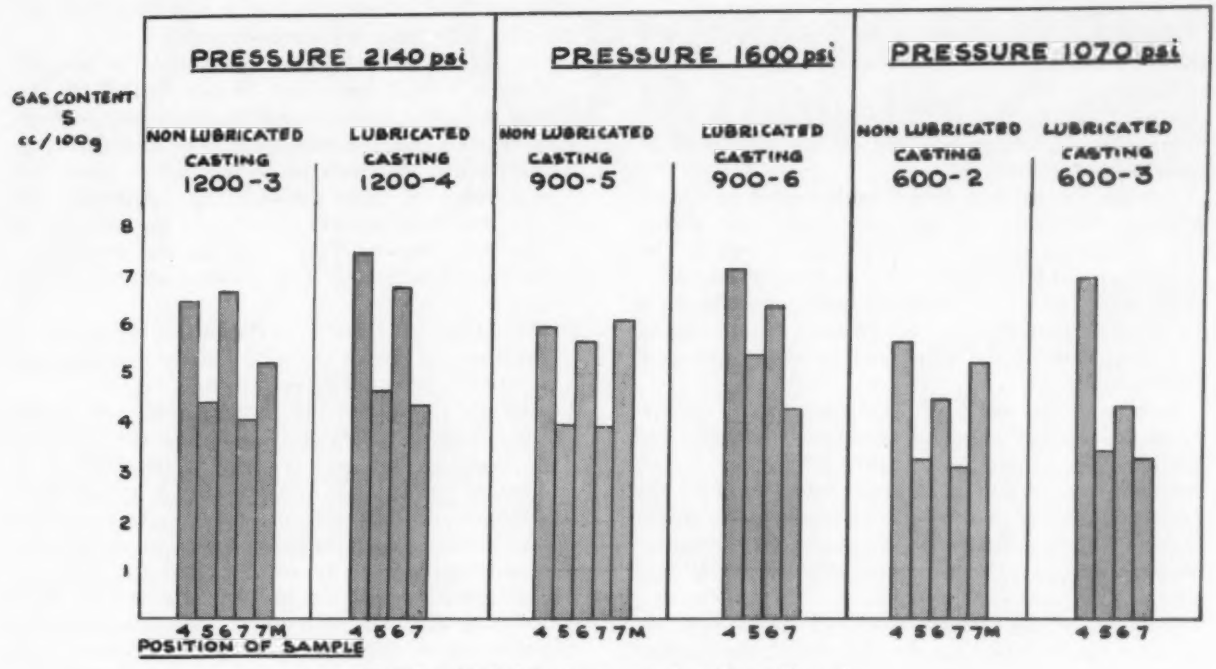


Fig. 11 — Variation of gas contents with position of castings produced at different injection pressures.

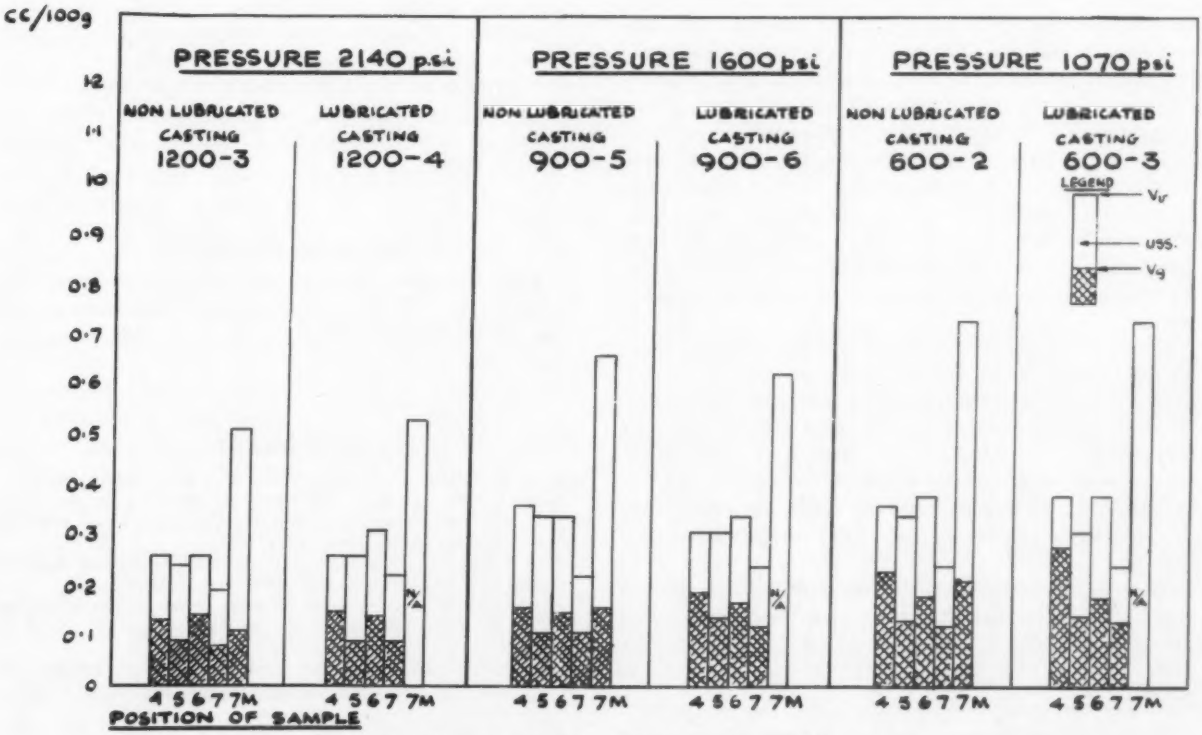


Fig. 12 — Functions V_v, V_g and USS at various positions on castings produced at different injection pressures.

the decrease in pressure from 2140 to 1070 psi. The gas content decreased slightly with decreasing pressure, however, because of the lower pressure, the overall effect was a slight increase in its volume before freezing (V_g).

This increase accounted almost completely for the change in density, since the unfed shrinkage remained relatively constant. The decrease in gas with lower pressure indicates that the venting became more efficient. This apparently was due to less turbulence at lower injection pressures.

The gas content was considerably higher in the regions remote from the gate, indicating that filling took place from the gate area towards the vents. The highest gas contents were found at positions 4 and 6 which were adjacent to the major overflow wells. Thus the general pattern of the gas porosity in the casting is a reflection of the flow pattern of the alloy in filling the die.

Positions 1 M and 7 M were quite small sections at the location of bosses at the extreme sides of the castings. These samples showed much lower densities than the other portions of the casting, however, the gas contents were of the same order. Thus, as might have been expected, the high porosity level was due principally to a high unfed shrinkage in this thicker area.

As before, it was found that the use of lubricant had no appreciable effect on the density of the castings although it caused a slight increase in the gas content.

CONCLUSION

By the use of the procedures described, commercial die castings can be examined in the laboratory to determine the distribution and nature of porosity present. Relationships have been developed allowing the interpretation of the results of the laboratory determinations to describe the conditions in the die cavity at the time of solidification. These techniques combined with standard metallographic procedures have proved useful for evaluating the quality of die castings, and may also find application for assessing the suitability of a die design and casting conditions for the production of castings with optimum properties.

Correct interpretation of the results obtained from the examination of isolated castings can be rather difficult, and the technique may prove of most value in studying and evaluating the effects of changes in die design. The method may also find application in assessing the effects resulting from the use of vacuum in die casting, and in fact some initial investigations along these lines have already been carried out.

Detailed results obtained from the examination of a number of die castings have been described. From these investigations a number of interesting findings concerning the nature of porosity in the castings were made:

1. Density measurements carried out on a large number of commercial die castings revealed a wide range of porosity levels. The densities of complete castings ranged from 6.59 to 6.36 g/cc, or, in other words, the volume per cent porosity ranged from 1.58 to 5.03. Individual sections cut from castings showed a wider range; the section showing the highest level of porosity had a density of 6.14 g/cc, i.e., 8.35 per cent porosity by volume.
2. For castings exhibiting a high degree of porosity (density 6.45 or less), over 50 per cent of the porosity was due to shrinkage. In the case of sections of extreme porosity (density 6.30 or less) shrinkage contributed as much as 70 per cent. Thus, the occurrence of gross porosity was associated with excessive unfed shrinkage due to an improper solidification pattern. This confirms the importance of maintaining correct thermal conditions in the die.
3. There was no apparent relationship between the incidence of surface porosity and the overall porosity level in the castings examined.
4. The gas content of the castings examined ranged from 4 to 8.5 cc/100 g (STP) for the complete castings, or, expressed in terms of standard conditions of temperature and pressure, it amounted to from about one-quarter to one-half the volume of the die cavity itself. Individual sections showed contents ranging from 2.5 to 15 cc/100 g (STP).
5. The gas present in the castings consisted mainly of deoxygenated air with some hydrogen and other minor constituents present. The hydrogen content (up to 25 volume per cent) can be accounted for as originating mainly from the reduction of water in the air and the decomposition of die lubricants.
6. The use of die lubricant even in excessive quantities had virtually no effect on the overall density of the castings. It did however cause appreciable increases in gas contents and changes in gas composition at some locations in the casting.
7. Variation in metal injection pressures in the range of 2140 to 1070 psi had only minor effects on density and gas contents of the two series of castings tested.

ACKNOWLEDGMENT

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MEETING THE CHALLENGE OF CONTROLLING QUALITY

by Lawrence S. Krueger

ABSTRACT

Although quality control has existed in the steel casting industry since the first castings were produced, there is need for stringent control, according to the author. He outlines the program which his company is using, highlighting the different facets. Melting, heat treating and sand quality control are covered, as are other parts of the program. The work of the Quality Control Committee is considered, as well as the training school program and the quality control records, cummunications and followup. Programs are needed that will increase the interest and responsibilities of hourly workers, establish supervision as the key to good quality control, use a minimum of paperwork and establish a mutually agreeable quality level with customers. This goal is necessary, according to the author, if the industry is to maintain a competitive position.

INTRODUCTION

In the past 18 months much has been said and written about quality control as it may or may not exist in the foundry industry. Local American Foundrymen's Society chapters are devoting more attention to this perplexing problem. The users of foundry products are speaking out critically concerning the inconsistency of the output as an industry. The Steel Founders' Society of American recently sent a marketing task force throughout the United States to discuss marketing problems, stressing inconsistent quality. Market research people are finding out that the resistance to greater usage of steel castings as an engineering material is twofold—cost and quality.

This is a severe criticism of present methods of production and quality control. What is done about eliminating or minimizing this criticism will determine the immediate and ultimate future of the steel casting industry. As steel foundrymen this challenge to the future growth of the industry cannot be ignored. Those who choose to ignore this problem may well find themselves in a struggle for survival.

The need for better quality control at the author's company was recognized over five years ago, and much has been done to improve the quality level of the castings produced. It is the intent here to present the procedures and techniques employed at the author's foundry which have aided in a substantial increase in quality level. Since pure technical answers do not adequately give a solution to controlling quality, the author will also present the philosophy that forms the foundation for the type of quality control program presently being employed.

CUSTOMER FACTORS AFFECTING QUALITY CONTROL

Quality control in the industry has existed since steel castings were first produced. Admittedly, it existed in the most informal possible manner. If this is true, why devote so much of time and energy to this particular phase of the business? To find the answer to this question we must begin with the people who use our product. Excluding possible cost reductions within the foundry itself, the only motivating factor in controlling quality is the customer.

What has occurred in the customer's plants that has created all this concern for quality control? The writer believes a number of things have occurred within their plants that has enlarged the problems of quality control for steel foundries. Some of the more important points are:

1. The employment of statistical methods for receiving inspection.
2. Automatic machining.
3. Increasing use of standards and incentives.
4. The use of cost reduction committees.
5. Increasing costs for castings.
6. Establishment of tighter specifications.
7. Competitive materials and processes.

All customers have at least one of these factors present; and many have all seven factors present in their operations.

The proper use of statistics for establishment of quality control is an important useful tool for management. This is recognized to be true, since many use statistics in establishing internal controls. How-

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ever, it must be pointed out that statistical control can be abused and misapplied. Curves, graphs, charts and formulas can become more important than the engineering function of the part being subjected to this type of control. It has been the writer's experience that some customers have gone too far in this approach of using statistical quality control.

Misapplication of statistical data in quality control will accomplish two things for the customer — 1) it will build unnecessary quality into the castings being produced and 2) it will increase the foundry's cost of production, and ultimately the selling price for the castings. This feature of using statistical control warrants a much closer look than it is currently getting as many castings are being rejected on minor deviations. Both the foundry and the customer would be much better off if the establishment of receiving inspection were mutually agreed upon prior to the production of the castings.

Machining

The other major change customers are making is in machining. Foundries no longer find the type of machining present where a customer can juggle a casting to compensate for variations. In the event machinery is present where compensations could be made for casting variations, objections will be raised from the customer's methods and standards procedures as established in their plant. Automatic machining is a real tartar; here the casting is virtually slammed into a machine, and completely machined in one operation. Any slight casting variation, such as warpage or core shifts, can cause the machining to be off with the end result being scrap. The writer's foundry is presently producing castings that weigh in excess of 400 lb that are completely machined in one operation in an automatic machine. This feature of automation is still in its infancy; castings users have only scratched the surface thus far. In the years to come this factor will affect quality control on all production castings that receive a machining operation.

As an industry, there are too many factors involved in production that little is known about. For example — 1) casting shrinkage as it pertains to pattern design, 2) dimension stability from casting to casting, 3) tolerances obtainable that can be held, 4) elimination of internal inclusions and defects and 5) machinability. These are all factors that are moving to the foreground in customer demands. These are the points that research and quality control procedures must conquer if the industry is to move ahead.

MANAGEMENT'S RESPONSIBILITY IN QUALITY CONTROL

What is the industry or individual foundry going to do about these areas? Here are several possible answers:

1. The status quo can be maintained and gradually go out of business.
2. Customer demands can be yielded to without any discussion.
3. Comprehensive quality control programs can be established to obtain optimum quality.

Each of these answers by itself is probably wrong. The probable answer lies within a combination of these three answers, and is extremely difficult to determine.

Unfortunately, the greatest strides forward in quality have not been made by desire to improve product. Each time there has been an upward movement in quality, the motivating force was usually customer demands. Most foundrymen would have to look long and hard to find an area where quality was improved due to a desire to improve for improvement's sake. By this it should not be inferred that all quality improvements should have been initiated by the foundries; however, there are improvements that should be made, or have already been made, that the industry should have been responsible for.

The philosophy of following minimum quality control to get past our customer's inspection must be eliminated. Improving quality and reliability as an engineering material will ultimately increase customer faith in the foundry industry.

The establishment of a quality controlled steel foundry operation must start with the top management of the company. While the actual establishment of quality control must start at the bottom of an organization and be built up, the positive philosophy must exist at the top and filter down. Management must not only be 100 per cent in agreement, but must also insist on 100 per cent cooperation from every member of the team. This must include all phases of supervision. Negative thinking or negative actions anywhere within this group can undo all the efforts to create and guarantee a quality controlled operation.

Developing Company Enthusiasm

How can foundry management create or develop enthusiasm for the improvement of quality necessary for survival in today's competitive market? There are many answers to this question — some of the more obvious ones are:

1. Management must honestly be trying to improve the quality of the castings being produced.
2. Management must provide proper facilities within which it is possible to produce quality castings.
3. Management must insist on the proper application of all scientific research results that can aid in quality control.
4. Supervision and staff personnel must get 100 per cent support in their efforts to produce better castings.
5. Management must be willing to scrap poor quality castings rather than use a calculated risk shipping policy.
6. Management must be willing to provide competent people.

These are only a few answers to this question. There are probably many more of equal importance and individual steel foundries would probably differ on the answers or importance of the answers.

Fortunately, most steel foundries are relatively small as measured in today's standards of company size. This creates the advantage that a more informal

quality control procedure can be followed. It is not only easier, but an absolute necessity, that top management in today's steel foundry take an active personal interest in all quality control problems that may exist.

The final point to be made under management's responsibilities is the role of line supervision in quality control. In the author's opinion, supervision is the key to quality control. Without the full cooperation of the supervisors, quality control will have trouble succeeding. The bulk of responsibility for quality control must be accepted by the supervisor. It has often been noted by the author that foundry supervisors are not always well informed on their own company operations. This lack of knowledge could prove detrimental in the maintenance of quality control procedures.

BASIC QUALITY CONTROL CONCEPTS

Quality control in a steel foundry can be divided into two general categories – process quality control and operating quality control. Process quality control should include all procedures where relatively constant flow of a material is involved. These operations at a typical steel foundry might be found in this category – 1) the production of metal, 2) heat treating control and 3) the production of sands.

Operating quality control is a general description of everything that is done, exclusive of process control, to produce a quality casting. Every foundry will differ quite widely in what procedures will be followed in establishing their operating quality controls. For the purpose here, the author will discuss the procedures that have aided in attaining a measurable improvement in the quality of the castings produced. The steps taken to accomplish this improvement were:

1. Creation of a quality control team of supervisors to maintain the procedures that were established.
2. Establishment of training schools for foundry personnel to both improve their workmanship, and to increase the degree of their responsibility for quality.
3. Improvement of communications and records that pertain to quality control.
4. Development of a follow-up procedure on problems pertaining to quality control.

MELT DEPARTMENT QUALITY CONTROL

Prior to attempting the solution of quality control problems created by increasing customer demands or requirements, today's steel foundry must have established positive quality control of the metal being produced. If inconsistent values of chemical and physical properties of the steel being produced exist, all other quality control procedures will prove to be of little or no value. The production of metal must be the starting point in the analysis or establishment of any foundry quality control procedure.

The author's company produces carbon and low alloy steels at a maximum rate of approximately 700 tons per month. Seven types of steels are produced in an acid electric furnace, ranging from dynamo steel to a molybdenum-manganese steel having 30 to 40 points of carbon. Off analysis chemistry, which could cause castings to be scrapped, amounted to 17,440 lb during 1960. This was accomplished while producing 2,616 heats of approximately 9000 lb each. The development of a high degree of quality control in melting can be attributed to:

1. Melters and helpers are paid on a quality control incentive system.
2. Purchasing of scrap is highly selective.
3. The size of all heats melted is approximately 9000 lb.
4. On all heats melting procedure is the same until additions are made to obtain the final chemistry.
5. A system of checks and records of procedures are maintained to give a history of every heat produced.

These factors, combined with the proper training of Melt Department personnel, have established a high degree of quality control in melting.

Figure 1 is a typical electric furnace log sheet employed by the author's foundry. The log sheet is filled out by the melter and contains a complete history of each heat produced. The log sheet is the first step in an adequate quality control procedure. The record of what has been done is important in the maintenance of a quality control procedure. In conjunction with this, a recording instrument is wired in the electric furnace curcuits to record the time on each heat, plus the time each tap of the transformer

	1	2	3	4	5	6
Heat Number	357	358	359	360	361	362
Type of Steel	25 Max.	35/40	25 Max.	40/50	Dynamo	35/40
Meter Difference	2640	2480	2320	2280	2320	2300
K.W.H. per Ton	660	620	580	570	580	575
Electrodes		170			170	
Number of Present Roof	2	2	2	2	2	2
Number of Heats Pres. Roof	20	21	22	23	24	25
Number of Heats Pres. Lin.	20	21	22	23	24	25
Number of Heats Pres. Ladle	6	7	8	9	10	11
Time power on	6:45A	8:14A	9:42A	11:02A	12:28P	2:09P
Time power off	8:07A	9:31A	10:51A	12:20P	1:55P	3:20P
Heat Tapped	8:09A	9:36A	10:56A	12:23P	1:58P	3:22P
FURNACE ADDITIONS:						
Purchased Scrap	3900	4200	3700	3600	4400	3500
Heads and Gates	5100	4600	4300	4300	4600	4900
Pigs and Spills		200	1000	1100		500
Scrap Castings						
Sub-Total	9000	9000	9000	9000	9000	8900
Molybdenum Oxide						
Mill Scale						
Iron Ore	250	250	250	250	450	250
Total Furnace Additions	9250	9250	9250	9250	9450	9150
Ladle Additions						
Manganese - Lump	73	68	73	67		68
Pulverized						
Silicon	53	52	55	50	125	30
Ferro Molybdenum						
Boron		2		2		2
Aluminum	9.5	9.5	9.5	9.5	40	9.5
Total Ladle additions	135.5	131.5	137.5	128.5	165	129.5
Furnace Operator	Felix	Felix	Felix	Felix	Felix	Stan.

Fig. 1 — Electric furnace record.

was being used. This merely serves as a check point to the power on and off as recorded by the melter, plus the elapsed time between heats.

The quality plan under which the melters operate has three parts — chemical analysis of the heat, man-hours per heat for the department and kwh/ton melted. This plan was reported upon in AFS TRANSACTIONS in 1952 by Tetzlaff.[1] The portion of the plan to be considered here is the incentive on chemical analysis, which is the most important part both from a quality control standpoint and potential incentive earnings for the melters. In carbon steel heats three elements are held within narrow limits by the melters to obtain a bonus for a quality performance. These are — carbon, manganese and silicon. The bonus ranges for these elements on a 0.40/0.50 carbon steel heat are:

Carbon .....0.41 to 0.49
Manganese .....0.65 to 0.75
Silicon .....0.40 to 0.50

Any values above or below these ranges inflict a penalty to earnings where the range has been held on another of the elements. Obviously the heat would not be scrapped if manganese or silicon were somewhat out of range. The point here is that melters can hold these ranges when their incentive pay is dependent upon it. Figure 2 is a daily laboratory report on the chemistry of the previous day's heats. This report is available the morning after the day the heats were produced, and immediately indicates any tendency for a drop in the quality of the steel being produced.

Date: 1-25-1961

Spec.	No.	Prel. C.	C.	Mn.	Si.	P.	Sul.	Cr.	Ni.	Mo.	Remarks
25 Max	357	16	24	65	38		042				
35/40	358	34	35	68	59		043				
25 Max	359	12	25	67	47						
40/50	360	35	42	67	55						
Dyn.	361	-	09	13	62		041				
35/40	362	30	33	63	38						
25 Max	363	15	25	69	50		044				
25 Max	364	15	23	70	50						
25 Max	365	14	27	75	55						
35/40	366	30	36	70	52						
25 Max	367	15	22	67	49						

Fig. 2 — Laboratory report.

Statistical Data Development

To demonstrate the results of using a quality control incentive plan for melters, statistical data were developed for the first 60 heats of 0.40/0.50 carbon steel produced in 1960. Table 1 is a compilation of the actual chemistry of these 60 heats, and Figs. 3 and 4 are control charts developed from the data of Table 1. These charts were developed according to procedures described by Johnson and Fisher[2] in AFS TRANSACTIONS in 1948. While these charts indicate the process is in control they do not indicate whether or not customer chemical requirements are being met. To check this Table 2 was developed. This table is

TABLE 1 — C-Mn-Si CHEMISTRY OF 60 CONSECUTIVE HEATS OF 0.40-0.50 CARBON STEEL

	Analysis, %				Analysis, %		
Heat No.	C	Mn	Si	Heat No.	C	Mn	Si
217	0.43	0.73	0.50	561	0.44	0.69	0.40
236	0.42	0.67	0.53	570	0.46	0.67	0.44
243	0.46	0.71	0.48	592	0.39	0.72	0.55
266	0.44	0.68	0.42	619	0.43	0.66	0.35
271	0.46	0.72	0.43	644	0.47	0.65	0.37
274	0.43	0.67	0.44	666	0.48	0.72	0.53
282	0.48	0.65	0.50	669	0.46	0.70	0.35
302	0.42	0.72	0.47	691	0.43	0.68	0.42
330	0.46	0.66	0.50	697	0.34	0.63	0.44
337	0.46	0.72	0.37	704	0.45	0.74	0.45
355	0.43	0.66	0.46	724	0.48	0.73	0.43
363	0.47	0.66	0.36	727	0.48	0.73	0.45
393	0.42	0.69	0.50	731	0.46	0.68	0.46
397	0.44	0.65	0.45	745	0.45	0.67	0.33
419	0.43	0.70	0.47	749	0.46	0.66	0.49
422	0.46	0.71	0.42	759	0.48	0.66	0.43
425	0.44	0.73	0.41	770	0.43	0.65	0.48
440	0.44	0.73	0.47	784	0.43	0.68	0.49
446	0.42	0.77	0.58	789	0.43	0.77	0.48
449	0.46	0.71	0.43	825	0.41	0.65	0.40
452	0.47	0.71	0.47	829	0.43	0.72	0.54
457	0.48	0.73	0.52	855	0.46	0.65	0.47
462	0.44	0.70	0.52	887	0.42	0.66	0.44
468	0.43	0.66	0.44	898	0.43	0.71	0.47
473	0.44	0.67	0.39	927	0.41	0.69	0.46
480	0.42	0.69	0.42	945	0.44	0.70	0.44
483	0.42	0.70	0.49	949	0.43	0.68	0.48
492	0.41	0.68	0.40	967	0.48	0.73	0.50
515	0.46	0.80	0.54	985	0.42	0.72	0.61
531	0.41	0.67	0.37	1007	0.45	0.68	0.38

a complete list of specifications for 0.40/0.50 carbon steel under which the author's foundry is operating. Examination of Table 2 indicates that specification no. 3 is the severest from a chemical standpoint. It is the author's opinion that a jobbing steel foundry should establish quality controls based upon the most rigid melting specification for the particular steel being produced, and produce all heats of that analysis to that specification. The interpretation here should be based upon steels that are regularly produced. Exceptional specifications only occasionally produced could be handled in a special manner. Using this criterion a second review of the statistical data indicate that the heats produced and tabluated in Table 1 met this requirement.

TABLE 2 — CUSTOMER SPECIFICATIONS FOR 0.40-0.50 CARBON STEEL

	Range, %		
Customer Spec. No.	C	Mn	Si
ACM 180	0.40 - 0.50	0.60 - 0.90	0.60 Max.
CH 186-6	0.40 - 0.50	0.60 - 0.80	0.60 Max.
1 E 3	0.40 - 0.50	0.65 - 0.85	0.60 Max.
PH 2	0.40 - 0.50	0.50 - 0.90	0.20 - 0.60
SC 3	0.40 - 0.50	0.50 - 0.90	0.20 - 0.60
1045 S 3	0.40 - 0.50	0.60 - 0.85	Not specified

While melters are not paid incentives on physical properties of the steel produced, it would be possible to analyze the results in the same manner as the chemistry. Physical properties of the types of steel

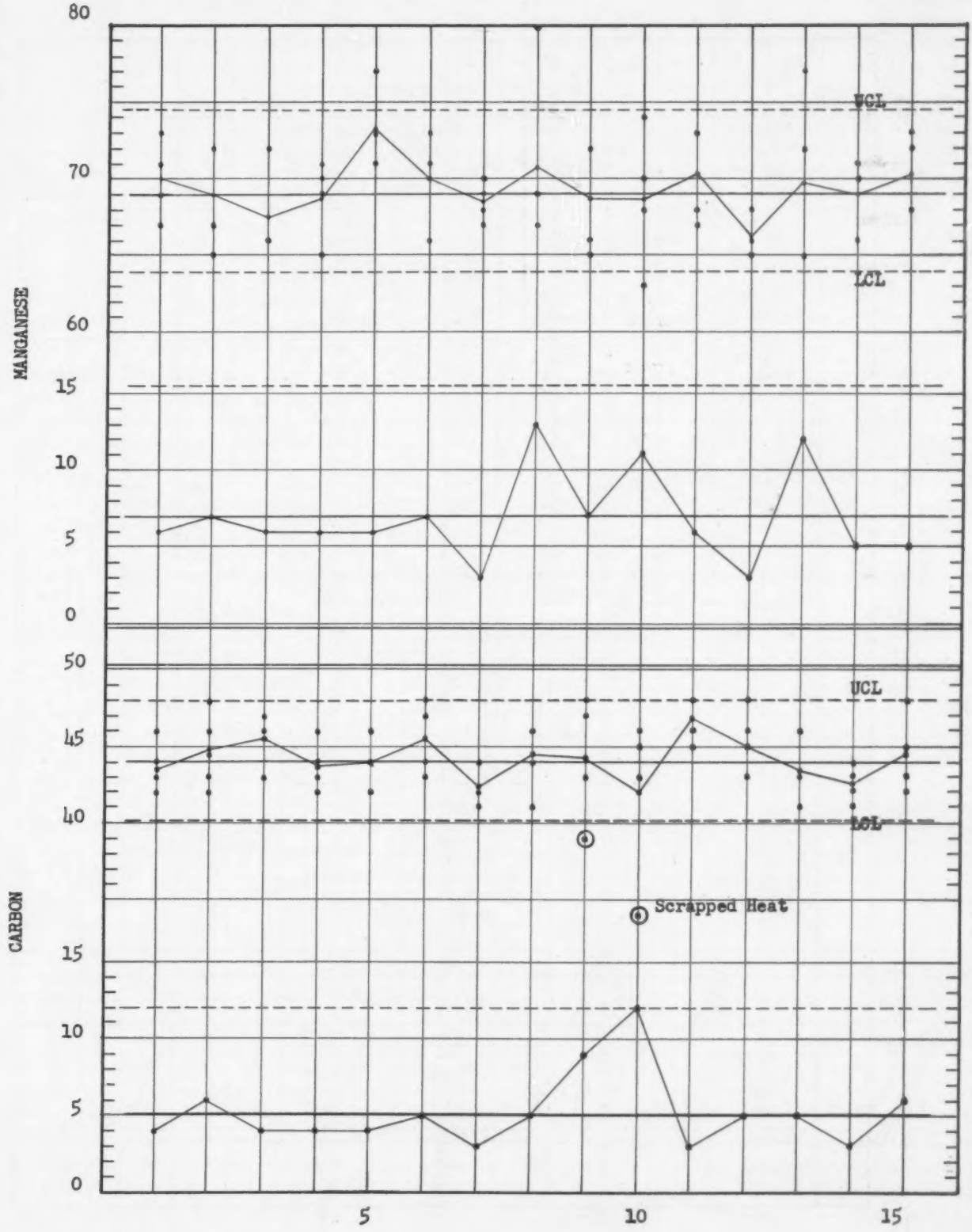

Fig. 3 — Control chart developed from data in Table 1.

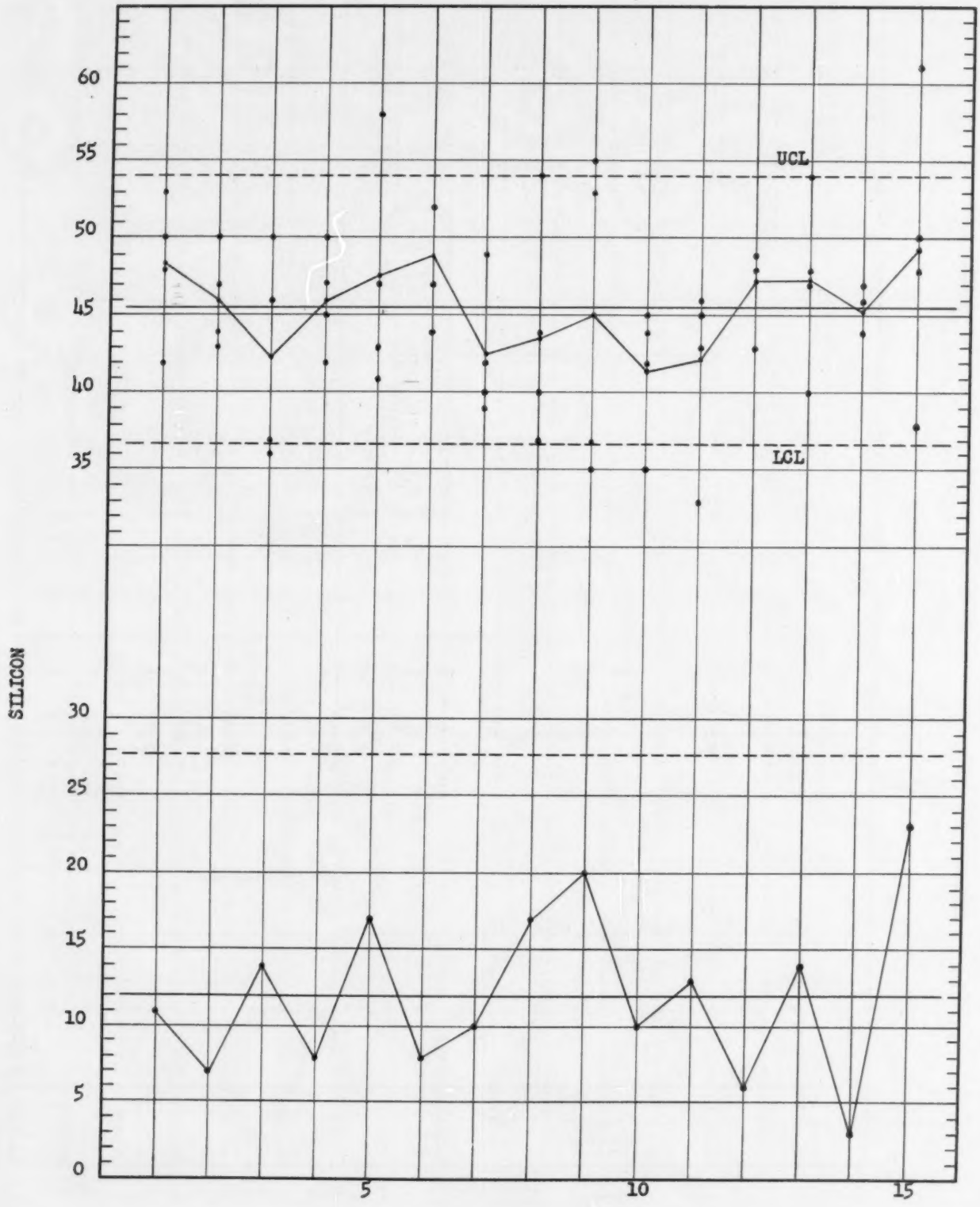

Fig. 4 — Control chart developed from data in Table 1.

being produced at the author's company are dependent upon two major factors — the heat treatment of the steel and the actual melting procedure in producing the heat. The point of concern to the Melting Department is one of procedure in producing the heats. Since procedures are firmly established and adhered to physical properties are controlled by employing the proper heat treatment.

The purchase of scrap for melting purposes cannot be minimized if good quality control is to be achieved. Each car of scrap received is visually inspected for size and type of scrap. If the purchased scrap does not meet specifications it is immediately rejected and returned to the supplier. The only other visual inspection made is to insure that the scrap is all plate and is not oily. A final chemical check is maintained on sulfur. This is done by running sulfur on at least 50 per cent of the heats produced. Since sulfur is accumulative, any high sulfur scrap would be caught within a day or two by observing the laboratory reports.

Melting Quality Control

Two factors previously maintained are closely related to maintaining uniform quality control in melting—uniform heat size and standard melting procedures. Uniform heat size, combined with selective scrap purchasing, allows a standard melting procedure to be developed. This procedure is to reduce carbon, silicon and manganese to pre-determined low levels, then ferro additions of silicon and manganese are added to obtain the desired result. Carbon is added by dipping electrodes to a definite depth in the bath for a calculated period of time. This procedure has resulted in the high level of quality performance previously mentioned. Along with this it should be noted that operating costs have been controlled as well as quality.

The final checkpoint in melting quality control is done during the actual pouring of molds. The pouring crew uses the heat record form (Fig. 5) to indicate the condition of the ladles and the heat itself. This report, along with the furnace log sheet, is kept together as a daily history of melt production. An immersion thermocouple, Figs. 6 and 7, is also used by the pouring crew to check metal temperatures in the pouring ladles. This instrument is not used on every heat, it is used as an occasional checking device to insure hot heats from the melting unit.

QUALITY CONTROL IN HEAT TREATING

In carbon and low alloy steels, designers and metallurgists are taking advantage of greatly increased strengths through closely controlled heat treating. Due to this need for higher strengths there has developed a strong trend to narrower allowable Brinell ranges. Customers who formerly allowed Brinell ranges of 50 to 60 points are currently specify-

Melt Heat No.	Analysis	Time In	Time Out	Temp.	Ladle Condition			No.	Molds Poured						Shell	Metal Pig.	Min. to Pour
					Bull	1 Ton	500#		Bench	Squeezer	Slinger	P.L.	Fl.	D.S.			
357	25 Max	8:12	8:40	2900				1	9	103	26					150	28
358	35/40	9:40	10:28	2890				2	17		4	64	2				48
359	25 Max	11:00	11:45	2910				3	9	253					49		45
360	40/50	12:25	1:00					4		132	4	43	1			75	35
361	Dynamo	2:05	2:35	2895				5		1	19					150	30
362	35/40	3:24	3:50	2920				6	11		9		4				26
363	25 Max	7:42	8:25	2920				7		216						125	43
364	25 Max	8:55	9:35	2930				8	12	62		30	6				40
365	25 Max	10:17	10:50					9			11		7				33
366	35/40	11:37	12:00					10			16						23
367	25 Max	12:52	1:30	2920				11		96	14						38
								12									
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								14									
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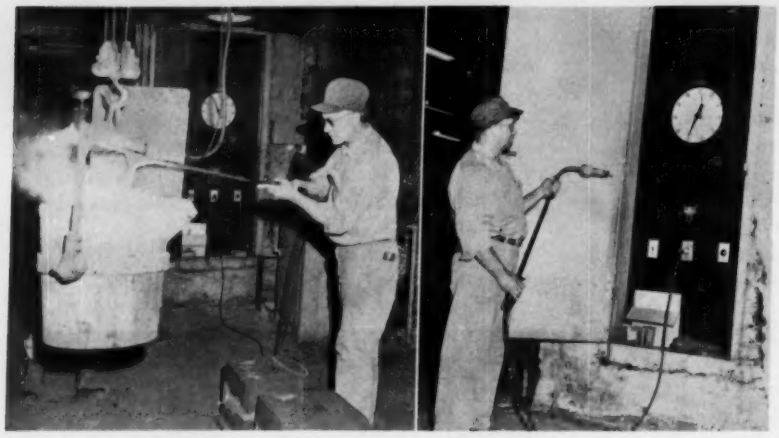
								21									

REMARKS:

Fig. 5 — Heat record of January 25, 1961.



Figs. 6 and 7 — Immersion thermocouple in use by pouring crew.

TABLE 3

Casting No.	Bhn	Casting No.	Bhn
1	311	26	306
2	311	27	306
3	311	28	311
4	311	29	311
5	302	30	285
6	302	31	285
7	302	32	311
8	285	33	302
9	302	34	302
10	311	35	302
11	302	36	302
12	302	37	311
13	285	38	285
14	285	39	302
15	302	40	302
16	302	41	311
17	302	42	302
18	302	43	311
19	302	44	311
20	302	45	311
21	302	46	285
22	285	47	302
23	302	48	302
24	302	49	285
25	302	50	311

ing ranges of 30 to 40 points. In order to meet this increasing demand, it is necessary to establish a quality controlled heat treating operation.

The first essential in a quality controlled heat treating department is a thorough knowledge of the chemistry of the steel. Rigid melting controls will substantially reduce difficulties in heat treating. It is the author's opinion that heat treating facilities should be an integral part of a steel foundry operation. This will accomplish two things—control of quality will be more easily accomplished and the cost of heat treating will be reduced.

Heat treating to Brinell specifications lends itself to statistical quality control. Table 3 contains the Brinell readings of 50 castings of a molybdenum-manganese steel that is liquid quenched and drawn to a Brinell range of 280-320. The plotting of statistical curves would prove to be of little value, since the customer specification will determine the upper and lower control limits. In this type of application, after a 100 per cent inspection demonstrates all Brinell readings are within the specified range a sampling procedure should be established to maintain control.

At the author's company, two methods of sampling are employed. If the customer has established a receiving inspection standard of sampling a given percentage of each shipment, the same procedure will be followed by the author's company's Inspection Department. If there is a lack of information available sampling will be done on a percentage basis, usually in the area of 10 per cent. One hundred per cent Brinell inspection has an extremely high cost factor, and is only employed in these instances:

1. On the first order or two on a new job until a proper sampling procedure has been established.
2. On the first order or two on an existing job where the specifications are changed.
3. On any job where a heat treating problem has developed. This will remain 100 per cent until the trouble is eliminated.
4. Where customer specifications require it, and an additional cost is charged to the job in quoting.

The remaining heat treating procedures include the usual standard operating procedures employed by most steel foundries. All heat treating equipment contains recording temperature instrumentation to serve as a check point on the heat treating operators. Since heat treating is a function of temperature and time based upon chemistry all heat treating specifications are established by the Metallurgical Department.

QUALITY CONTROL OF SANDS

The necessity for adequate quality control of sands and bonding materials is known by all steel foundrymen. On a weight or volume basis this is the largest single material used in today's steel foundry. Therefore, it is logical that a great deal of time and effort has been expended in research to produce the best possible economic sand mixes. The maintenance of the performance of the sand mixes is a function of quality control. The degree of quality control applied to sands must, to a great extent, be dependent upon the class of work being produced by the individual steel foundry. Because of this, it is

Molding Station	Moisture	Perm.	Green Strength	Hardness	Where Tested	Remarks
Squeezer	2.50	170	6.3	82	Station	Reclaimed Facing
Squeezer	2.40	180	6.1	83	Station	Reclaimed Facing
Squeezer	2.60	170	6.3	83	Station	Reclaimed Facing
Squeezer	2.60	170	5.9	82	Station	Reclaimed Facing
Squeezer	2.30	180	6.4	83	Station	Reclaimed Facing
Squeezer	2.40	180	6.2	81	Station	Reclaimed Facing
Floor	3.60	130	5.6	81	Station	Reclaimed Facing
Floor	3.40	140	5.4	82	Station	Reclaimed Facing
Floor	3.60	130	5.3	81	Station	Reclaimed Facing
Floor	3.30	140	5.7	82	Station	Reclaimed Facing
Blower	5.40	60	3.3	72	Mill	New Sand
Blower	3.80	100	2.8	69	Station	New Sand
Blower	3.20	110	2.2	66	Station	New Sand
Blower	3.00	110	2.1	65	Station	New Sand

Fig. 8 — Daily sand report form, of January 25, 1961.

impossible to have firmly estalished quality control procedures that will apply to all steel foundries.

The author's foundry produces castings up to approximately 3,500 lb in weight, using loose and production pattern equipment on snap flask molding units and tight flask molding units. On all molding a dry reclaimed facing sand is used back up with heap sand. All core sands are made with new sand which is an AFS 63 to 68 screened and dry Portage sand. The desired properties of molding sand vary with the type of casting being produced, and with the type of molding being employed to produce the castings. The basic tests employed on molding sands are — 1) moisture, 2) green strength, 3) pH, 4) standard ram hardness and 5) permeability. Core sand mixes are checked more frequently than molding sands, and in addition to green properties, core sands are checked for dry properties.

Once again it can be pointed out that records of what has been done are essential to a good quality control procedure. As in melting, the author's company maintains adequate records of sand mill performance to insure that proper operating procedures are followed. Two daily reports are maintained by the Sand Technician; 1) the daily sand report (as illustrated in Fig. 8) which is a random check of facing sand properties, the samples to be checked are usually obtained at the molding station and 2) a record of the total sand production by types of sand (Fig. 9). In conjunction with this a recording strip chart is wired into each sand mill electrical circuit as a check point on mulling time for each batch of sand. Figure 10 is a chart taken off of a sand muller.

Type of Mix	1st Shift	2nd Shift	3rd Shift	Total No. Mixes
Heap Sand	169	85		254
Facing	38	12		50
Strong Oil Sand	1	1		2
Collapsible Oil Sand	3			3
Blower Sand	5			5
Zirconite Core Sand				
Ladle Sand	1			1
Special Sand				
Down Time Mill No. 1	28 Min.	1 Hr.		1 Hr. 28 Min.
Down Time Mill No. 2	26 Min.	1 Hr. 14 M.		1 Hr. 40 Min.
Remarks:				

Fig. 9 — Sand laboratory record of daily mill mixes, of January 25, 1961.

The amount of checking is fairly constant as pertains to sands; approximately 50 per cent of the batches of core sand are checked for green properties, while approximately 25 per cent of the batches of reclaimed facing sands are checked. The best criterion of adequate quality control in sands is the casting quality in the cleaning room. Therefore, sand technicians are required to constantly check castings prior to head and gate removal, to prevent any tendency for a sand defect becoming a major problem. This is pointed out here because the author feels it is much too easy to blame quality problems on sands when the casting is partially processed by the cleaning room. Oftentimes a casting with headsand gates on it will point to the fact that a quality problem may be one that involves the level of workmanship rather than the quality of the sand.

Sand Screen Analysis

The final point to be made concerning sands is the screen analysis checks being made by the author's company. The screen analysis of every car of new sand received is checked to determine that it meets the specification. Reclaimed sand and heap sand are regularly checked to insure that screen distribution and screen analysis are within the operating ranges that have been established. Figure 11 is a visual type of report that is posted in the sand laboratory where everyone can see it. This gives the AFS number as well as the screen distribution of the reclaimed and heap

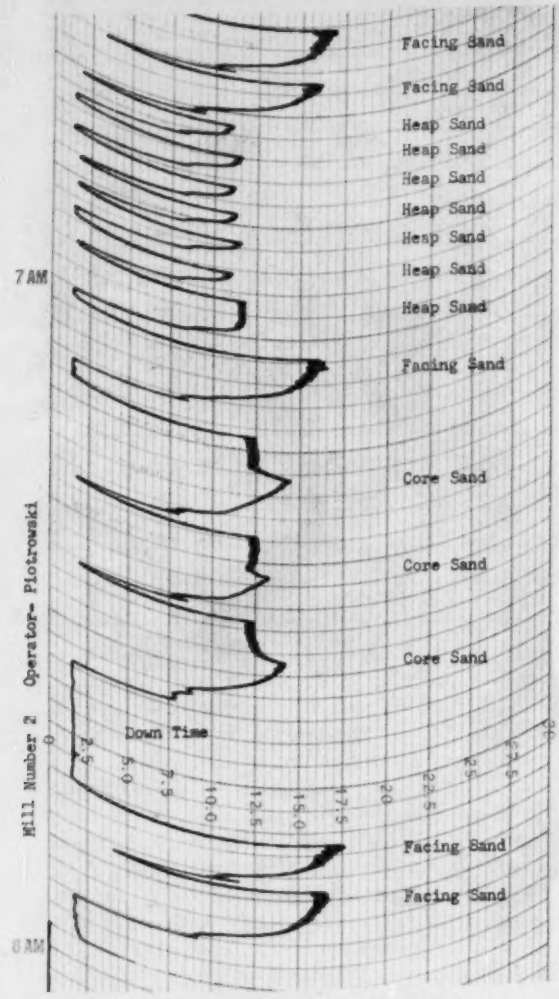


Fig. 10 — Chart taken off sand muller.

sands. It is felt that a visual type of report is better, since the data are more easily read. Another advantage is the ease of comparison to previous reports to observe any tendency for a shift in screen analysis.

While sand control at the author's foundry is not as brief as described here, it is felt that great detail on this subject would be repetition of many previous papers and reports by others. It is hoped that indicating the type of control employed will suffice on the subject of sand quality control.

QUALITY CONTROL COMMITTEE

The establishment of quality control responsibilities can vary quite widely from company to company. It is believed that controlling quality is a prime responsibility of supervision; however, most steel foundry supervisory groups are fairly large, and would be difficult to work with in its entirety. Because of this problem, it is felt that a quality control team or committee should be established from within the supervisory and management group. The group should be as small as possible, and should consist of those people who would normally have a wider knowledge of the overall quality control problems.

With this premise in mind the author's company established a quality control committee to act as an advisory group in establishing and maintaining quality control procedures. The members of this committee are the works manager, plant metallurgist, chief inspector and quality control supervisor.

The purpose of this committee is to act as a central clearing house for supervision in the matters of quality control. Each individual on the committee watches specific areas of the quality control program, and handles the problems that develop within that area. The committee in no way circumvents supervision, nor does the committee relieve the responsibility of supervision for quality control.

This committee approach has resulted in improved quality control. The paper work involved in estab-

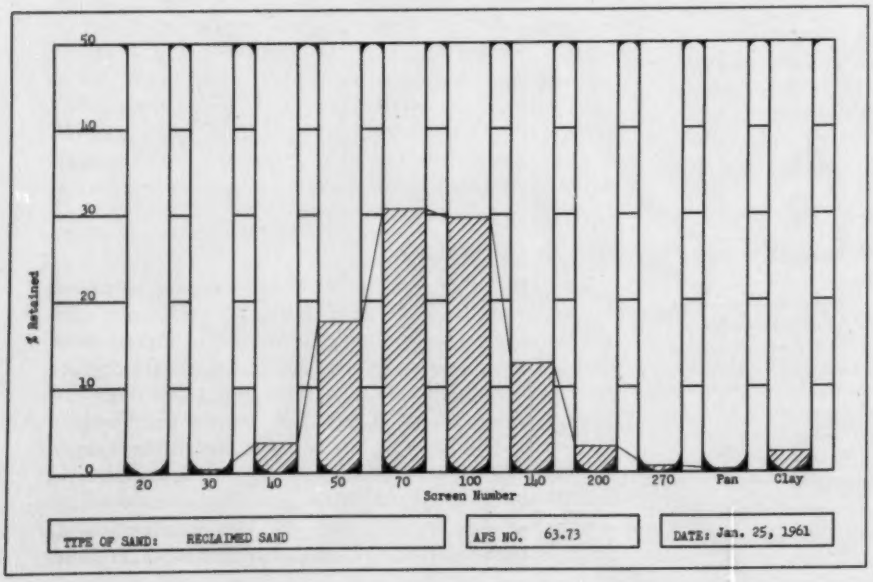


Fig. 11 — Visual type report posted in sand laboratory.

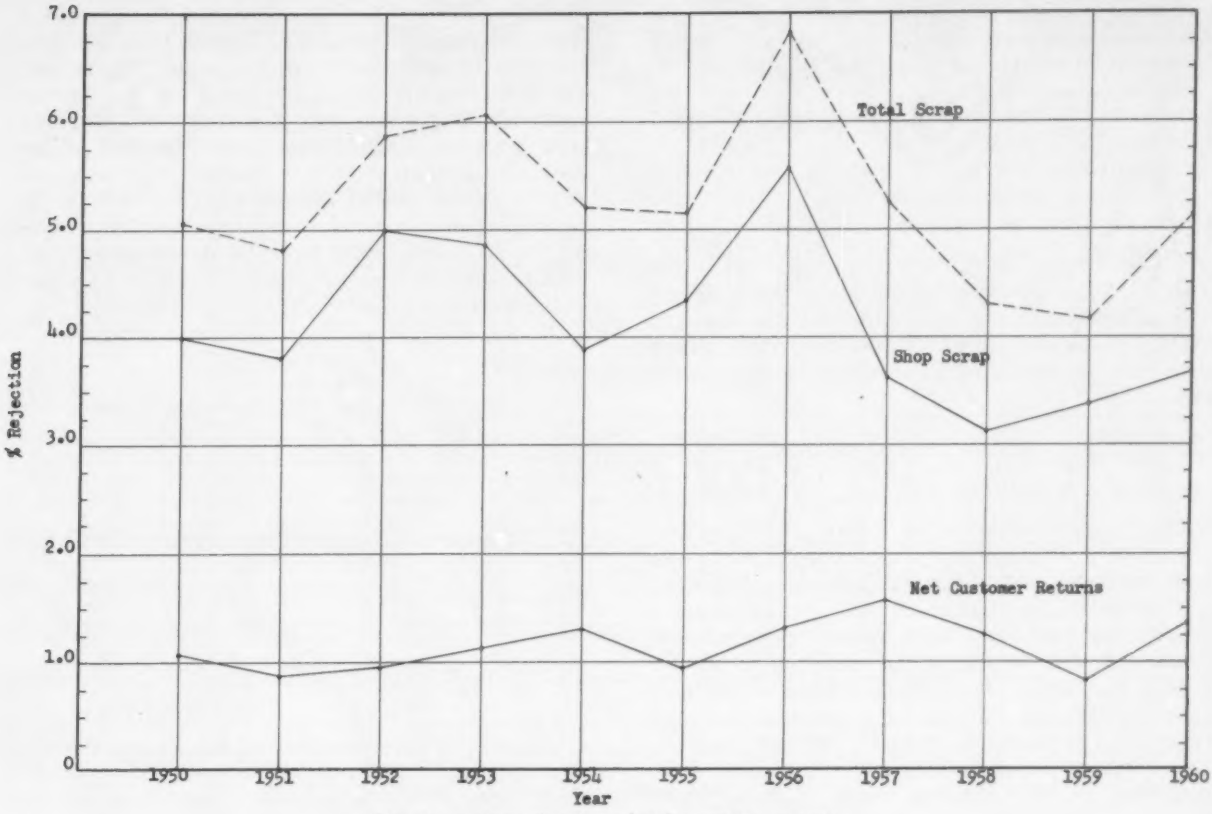


Fig. 12 — Chart showing need for quality control.

lishing and maintaining quality control procedures has been minimized. The results of this effort are hard to evaluate in dollars and cents, since customer relations cannot be evaluated in terms of money. To demonstrate the need for quality control, Fig. 12 was developed. This shows the percentage of net customer returns, shop scrap and total scrap for the author's company for the last ten years. The general trend prior to 1956 was up while the trend since 1956 has been down; 1960 shows a reverse in trend again.

In the author's opinion, the reversal in 1960 was due to a substantial increase in customer requirements. It has been the author's experience that customer returns will closely follow shop scrap—as internal scrap increases, customer returns will also increase.

TRAINING SCHOOLS FOR IMPROVED QUALITY

One of the first problems that arose in establishing improved quality control was the need to increase the interests and amount of responsibility of the hourly workers. It was felt that although supervision is the key to quality control the hourly worker has a high degree of responsibility for the level of quality that can be obtained. Any method that will increase his desire to do a better job, or increase his pride of workmanship, is highly desirable.

It was decided to run a training school on a voluntary basis to determine the amount of interest the hourly man had in his work. The school was established on Saturday mornings, with attendance strictly optional on the part of the men involved. No one was paid for attending, although free lunch was served at the conclusion of the sessions. Since the cleaning room cannot improve much on the castings it received from the foundry, the decision was made to concentrate the effort into three departments—coremaking, molding and pouring. Incidentally, no one within the organization was excluded from attendance at any session regardless of the department they worked for.

Four sessions were planned for four consecutive Saturday mornings—no. 1—sand and its use, no. 2—molding practice, no. 3—core room practice and no. 4—pouring.

All lectures were prepared and delivered by the supervisors from the quality control committee and departments involved. Each session was allowed ample time for a question and answer period, and all questions asked were answered.

The following is a complete list of the lectures presented at the four classes held.

1. "Why We Use the Sands We Do," by the Plant Metallurgist.
2. "The Proper Use of Sands for Quality," by the Quality Control Supervisor.
3. "Essentials to Good Cores," by the Plant Metallurgist.

4. "Quality Cores for Quality Castings," by the Core Room Supervisor.
5. "Selection and Use of Tools and Equipment," by the Molding Supervisor.
6. "Quality Workmanship Equals Quality Castings," by the Molding Supervisor.
7. "Quality Considerations in Pouring," by the Quality Control Supervisor.
8. "Proper Pouring Procedures," by the Pouring Supervisor.

In order to correlate attendance at these schools it is necessary to have some idea of employment in the departments involved. At the time these schools were held, the following employment by departments existed.

Molding .....35 men
Core Room .....15 men
Pouring & Indirect .....45 men

The average attendance at school sessions was approximately 50 hourly men, with a high of 65 at the sand session to a low of 42 at the core room session.

The lecture series paid off in a greater desire to do a better job. Shop scrap showed an appreciable drop after the lecture series was concluded. The hourly men began to understand some of the problems encountered in producing castings that meet customer requirements. Foundry workers were observed taking a keener interest in the castings being processed by the cleaning room. The feeling of being an important part of the organization was imparted to the men who attended the lecture series. All of these observations has sold the author's company on the need for putting more trust and responsibility in the hourly workers' hands. An informed group of hourly people under a qualified supervisor cannot help but improve the products produced.

QUALITY CONTROL RECORDS, COMMUNICATIONS AND FOLLOWUP

One of the most important areas of quality control is in the necessary records being maintained, and the means of communications. If a truly workable quality control procedure is to be established, the records kept must be the minimum required to do the job. Communications must be such that everyone concerned with any problem is immediately informed about the problem. To accomplish this is extremely difficult, and the author cannot say the present system employed meets these requirements. What has been developed thus far has aided in reducing confusion; however, the system does not always perform to perfection.

At the author's company all records pertaining to shop scrap and customer returns are kept on a monthly basis. Daily reports are made, and the cumulative records are maintained. While some foundries advocate posting shop scrap results at the various molding stations, the author's company maintains the records on a bulletin board at the shop entrance. Each casting returned from a customer is reviewed by the supervisors involved in the production of the particular casting.

The forms employed to report shop scrap are illustrated in Figs. 13 through 15. Figure 13 is the daily scrap report made out by the Inspection Department. On this form all castings scrapped for the day are recorded. The Production Department transfers the data from this report to production records. If any particular pattern number is running high scrap, an A.V.O. (Avoid Verbal Orders) form is issued to the quality control supervisor for investigation. Figures 14 and 15 are the scrap report as posted in the shop, and is illustrated to demonstrate the type of report being used.

DAILY SCRAP REPORT
DATE_____

Customer	Pattern	No. Pcs.	Reason	#/Pc.	Total Weight	Molder	Remarks

Fig. 13 — Daily scrap report form.

Figure 16 is the form used to list castings returned by customers. Four copies are made out—1) inspection copy, 2) works manager's copy, 3) sales copy and 4) accounting copy. In addition, the Inspection Department keeps a record of returns by customer and pattern number. Figure 17 is the form employed, and tells at a glance the customer rejection rate on any particular job during the year. This record has proved to be of great value in establishing quality control requirements for an individual job.

In a jobbing operation the type of production does not lend itself to statistical scrap analysis. The cost of developing the data would not be warranted when compared to the results obtained. In the author's opinion, it is the responsibility of supervision to watch the causes for internal rejection, and immediately take steps to correct the situation. The chief inspector and Inspection Department should be relied upon to catch abnormal situations and should immediately call attention to the problem.

The final form used in evaluating and controlling shop scrap and customer returns is illustrated in Fig. 18. This form is used for internal as well as external quality complaints. On internal problems the form is filled out by inspection in duplicate, the original kept for the Quality Control Committee for follow up while the copy is forwarded to the quality control supervisor for action on the problem. Each week the reports are reviewed, and corrections are reported in writing as a part of the permanent records.

Job History File

The establishment of a job history file has been a great aid in quality control. A job history file starts with the blueprint of the part and contains all pertinent data on the part. If it is a new job the sample processing form (Fig. 19) and a copy of the sample

DEPARTMENT		Squeezer	Bench	Floor	Slinger	Pin Lift	Core	Shell	Total Weight	%
Weight of Scrap To Date — Pouring	Miss Run									
	Slag									
	Poured Short									
	Shifted									
	Misc.									
	Total									
Weight of Scrap To Date — Melting	Pin Holes									
	Off Analysis									
	Cold Heat									
	Wet Ladles									
	Total									
Core Room										
Cleaning Room										
Inspection										
Supervision										
Total Scrap To Date										
Total Production To Date										
% Scrap To Date										

Fig. 14 — Production scrap report form.

MOLDING STATIONS		PRODUCTION TO DATE POUNDS	SCRAP TO DATE POUNDS	% SCRAP
FLOOR MOLDING	6. Pomeroy			
	8. Sereno			
	11. Woyak			
	12. Blakesmith			
	13. Manske			
	17. Daiedzic			
	21. Gondek			
	23. Csajkowski			
	25. Wiechowski			
	30. Banach			
	31. Pogorselski			
	34. Wiskowski			
	35. Cichosz			
	42. Banaszynski			
	TOTAL			
BENCH	3. Ilovshek			
	32. Ledesma			
	TOTAL			
FLOOR MOLDING	5. Baker			
	9. Schults			
	15. Perry			
	16. Jaster			
	22. Schults			
	48. Wagner			
	TOTAL			
MACHINE MOLDING	Day Shift			
	Night Shift			
	TOTAL			
	Day Shift			
	Night Shift			
	TOTAL			
TOTAL MACHINE SCRAP				
Dry Sand Molding				
Shell Molding				

Fig. 15 — Production scrap report form.

RETURNED CASTING REPORT

Customer _____ Date _____

Pattern No. _____ No. Pieces _____

Selling Price _____ Shipping Weight _____

Reason For Rejection _____

Disposition _____

By _____

Fig. 16 — Returned casting report form.

shipping letter (Fig. 20) will be filed with the blueprint. Any excessive shop scrap as reported by inspection, or any returned castings data recorded on the forms illustrated in Figs. 16 and 18, will also be filed in the job history folder. The records take several years to develop before they can be of any real value. A point that should be made here concerning the blueprint and sample forms is that the level of quality control required for any new job is established at this point. Much too often this factor is overlooked until production has been started on the job.

One of the greatest problems in maintaining quality control procedures is to establish a method to guarantee that a solution to a quality problem will be carried out on all subsequent orders for the part

REJECTION REPORT

CUSTOMER _____ PATTERN NUMBER _____

Date Received	No. Pcs.	Reason for Rejection	No. Scrpd	No. Salv.	No. Pcs.	Remarks

Fig. 17 — Customer rejection report form.

CUSTOMER: _____ DATE: _____

PATTERN NO. _____ CUSTOMER REPRESENTATIVE: _____

QUANTITY: _____

QUALITY COMPLAINT: _____

DECISION REACHED WITH CUSTOMER: _____

BY: _____

CORRECTION & REVIEW BY INSPECTION DEPARTMENT: _____

BY: _____

DATE: _____

SKETCH: _____

Fig. 18 — Quality complaint form.

CUSTOMER _____

SAMPLE FORM OR NOTE BY _____

Pattern No. _____ Old Loose ☐ New Loose ☐ Revised Loose ☐

Revised ☐ Permanent ☐ Master ☐

Amount of Pcs. to One Mold _____

Pattern Received _____

Month_____ Day_____ Year_____

Date Patt. Rigged & Ready for Cstg. _____

Month_____ Day_____ Year_____

Date Cast _____

Month_____ Day_____ Year_____

Started to Process _____

Month_____ Day_____ Year_____

Amount of Pcs. Required to Submit as Samples:

Customer Check _____ Our Check _____

Appearance of Risers _____

Gates _____ Surface _____

Molding Supv. Informed	YES ☐	NO ☐
Gamma Ray Before Welding	YES ☐	NO ☐
Gamma Ray Report	GOOD ☐	BAD ☐
Burn Out Anneal	YES ☐	NO ☐
Reweld	YES ☐	NO ☐
Prints for Checking	YES ☐	NO ☐
Dimensional Check	YES ☐	NO ☐
New Samples Reqd.:	YES ☐	NO ☐
Weld & Anneal After:	YES ☐	NO ☐
Anneal:	YES ☐	NO ☐

Ship ☐ Hold ☐ By Whom: _____

Sample Forms Contain Needed Information for Customer:

YES ☐ NO ☐

Heat Treatment Reqd.	YES ☐	NO ☐
BRN Reqd.	YES ☐	NO ☐

Actual BRN _____

Customer Analysis: C ☐ M ☐ S ☐ Moly ☐

DATE TO SHIPPING DEPARTMENT _____

DATE SHIPPED _____

Fig. 19 — Sample processing form for new job.

_____

_____

_____

Attention: Mr. _____

Subject: Sample Casting No. _____

Gentlemen:

We have included in our shipment of _____

_____ sample castings, plainly marked,

Attention: Mr. _____

We would appreciate your comments regarding this / these casting / castings at your earliest convenience.

Very truly yours,
Chief Inspector

CC: _____

LIST OF SAMPLE CASTINGS

Fig. 20 — Sample shipping letter files with blueprint.

involved. To accomplish this a special card was designed, as illustrated in Fig. 21. This card is filled out and filed with the Sales Department records for the job. When a new order is placed on the part, the sales clerk pulls the card and forwards it to the person indicated. This procedure of keying quality corrections to incoming orders has accomplished the job desired with a minimum amount of clerical effort. It is the author's opinion that this procedure of keying only critical jobs eliminates the need for a job order system.

The final area of records involves the heading and gating of pattern equipment. In a jobbing operation, both production and loose pattern equipment are employed. One of the problems of quality control is to maintain a record of any changes in heading and gating. To accomplish this the form in Fig. 22 was developed, for the purpose of recording original risering, and any subsequent changes to the

CUSTOMER _____ PATTERN NO. _____

MEMORANDUM FOR: _____

NOTE: This card is to be given to the above immediately upon the receipt of a new order on this pattern.

NOTES

_____

_____

_____

_____

_____

_____

_____

_____

Fig. 21 — Card designed to carryover any quality problem solution to subsequent orders.

CHANGE IN RIGGING FORM

Customer _____ Pattern Number _____

Molding Unit: _____ Shipping Weight: _____

No. per Mold: _____ As-Cast Weight: _____

Size of Flask: _____ As-Cast Yield: _____

Cope Ht: _____

Drag Ht: _____

Remarks: _____

Sketch on other side

Fig. 22 — Rigging change form.

risering. This eliminates the requirement of relying on someone's memory as to what has been previously tried when a new problem develops on a job. It is also extremely valuable in loose work, since the sketch of what was successful on previous orders will indicate the proper risering and gating to the supervisor.

One of the important features of the system employed by the author's company has been regular quality control visits to customer plants by operating personnel. This procedure has proved to be extremely helpful in the reduction of quality problems. Only those plants where the foundry personnel can see the customer's inspection and shop personnel are visited. In this manner it is possible to determine any minor problems that are irritating to the customer. When the awareness to the problem exists, action is taken immediately to eliminate it. To control this a report form (Fig. 23) was developed. The man making the visit is required to fill out the form, and when the problems indicated are eliminated the form is filed alphabetically by customer. This establishes a record of the visits made and a record of the problems encountered. Incidentally, the customers have generally expressed approval of this type of call by operating personnel.

CUSTOMER _____ DATE OF VISIT _____

CUSTOMER PERSONNEL CONTACTED:

_____ _____ _____

_____ _____ _____

_____ _____ _____

_____ _____ _____

REPORT OF CALL:

BY: _____

Fig. 23 — Quality control customer visit form.

NEW EMPHASIS FOR VARIABLES CONTROL

Whenever a casting is produced, the foundry producing the casting is striving to accomplish one thing —reproducibility. The entire effort is being expended to have every casting produced from any given pattern exactly like every other casting produced from that pattern. Thus far this has not been accomplished while maintaining a reasonable cost of production at the same time. The foundry industry has an exceptionally high human element in its production. This factor presents a difficult problem to scientific and quality control efforts. Once a satisfactory quality level has been achieved on any job, how can reproducibility at a competitive cost basis be achieved?

The author's company does not purport to know the answer to this problem. However, there are some steps a steel foundry can take that will aid in approaching a solution to reproducibility. One of the first steps should be to develop adequate laboratory facilities to control the production of metals and sands. Figures 24 through 28 are views of recently installed laboratory facilities at the author's company. One of the reasons the industry controls the production of metal and sand as well as it does is due to the means in the companies for checking the results of production.

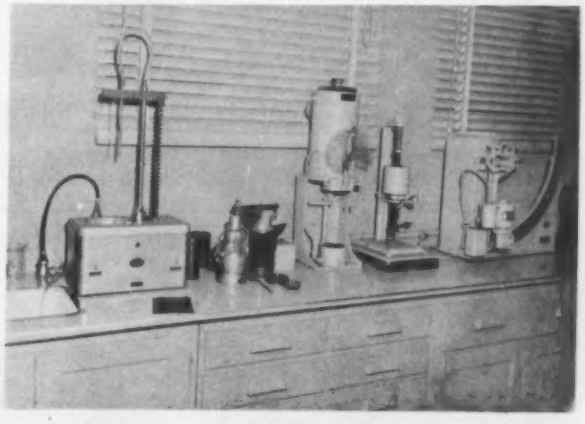
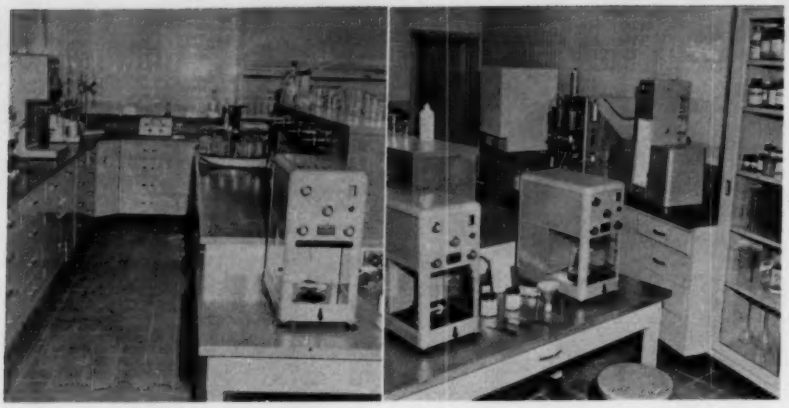


Fig. 24 — View of sand laboratory.

Chemical and physical properties of metal, as well as sand properties, are not subjected to opinions, the results are determined by laboratory inspections. Can today's steel foundry continue with only the barest rudiments for these facilities? The author thinks not, not if integrity as producers of an engineering material is to be established.

How many steel foundries have as an integral



Figs. 25 and 26 — Views of chemistry laboratory.

part of their facilities nondestructive testing? Facilities such as x-ray, cobalt and magnetic particle inspection equipment. Recently the author heard a quality control manager of a large user of castings cite an annual rate of rejection of $847,000 on casting purchases of 18 to 20 million dollars with a machining loss of $147,000. The causes for rejection were:

61 per cent.....Internal defects
25 per cent.....Visual defects
12 per cent.....Dimensional variations
2 per cent.....Miscellaneous defects

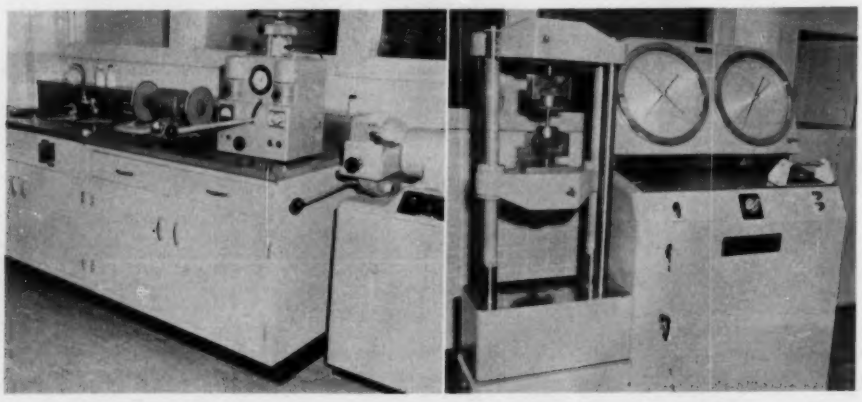
This indicates the industry must do much more in eliminating the problem of internal defects; nondestructive facilities is a step in that direction. At the author's foundry Cobalt 60 and magnetic particle testing are part of operations (Figs. 29 and 30). In the example cited, if one-half the rejections for internal defects could be eliminated, the dollars saved for the foundries involved would exceed a quarter of a million dollars. This type of savings will pay for a lot of nondestructive testing.

Dimensional control is becoming a critical factor in final inspection for a steel foundry. At the author's company the use of straightening processes, gages and checking fixtures is increasing at a rapid rate. These tools are a necessity if proper quality is to be maintained. Figure 31 is a recently acquired 500 ton press for straightening. Figures 32 and 33 are illustrations of the employment of gages and fixtures in final inspection. The production of castings to conform to inspections requiring the use of gages and fixtures is a function of quality control. Proper steps taken in core making and molding will minimize the problems in the cleaning room.

Can the money spent on quality control be afforded? Perhaps the best answer is, can we afford not to spend it? Quality control should save money if it is properly conceived and executed. In the author's opinion, the savings in quality control can be derived from two things, a reduction in internal scrap and a reduction in customer returns and allowances. Values can be placed on each of these items, and direct savings calculated from the reduction obtained. Dollar values are not quoted here, since they are a function of an individual foundry's operating costs and selling price.

CONCLUSION

Results of the program the author has described have been encouraging. However, what has been done is not enough. After several years of honest effort to improve quality it can be noted that the author's company is just beginning to catch up to customer demands. It is not sufficient to just catch up, but must move ahead of customer requirements in quality. The effort to move ahead cannot be accomplished in a short period of time. Installation of systems or people will not suddenly make a foundry a



Figs. 27 and 28 — Views of physical laboratory.

Fig. 29 — Nondestructive testing.

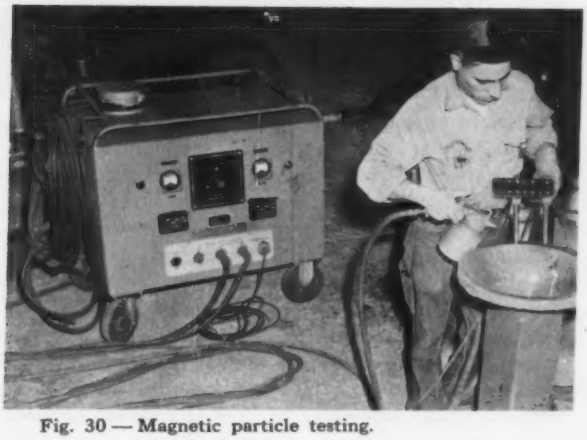


Fig. 30 — Magnetic particle testing.

high quality shop. Education or re-education through a gradual step-by-step program will accomplish an improvement in quality; however, a vital factor is an aggressive dynamic management that is not content to be second best.

The steel foundry industry needs quality control, even though it currently has quality control to varying degrees. What the industry needs to do is establish programs that put the responsibility where it belongs. Programs are needed that will increase the interest and responsibilities of hourly people, establish supervision as the key to good quality control, use a minimum of record keeping and clerical work and, finally, to establsh a mutually agreeable quality level with customers. This must be the goal of quality control if the industry is to maintain a competitive position.

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2. H. H. Johnson & G. A. Fisher, "Statistical Quality Control a New Tool for the Foundryman," AFA TRANSACTIONS, *vol. 56* (1948).

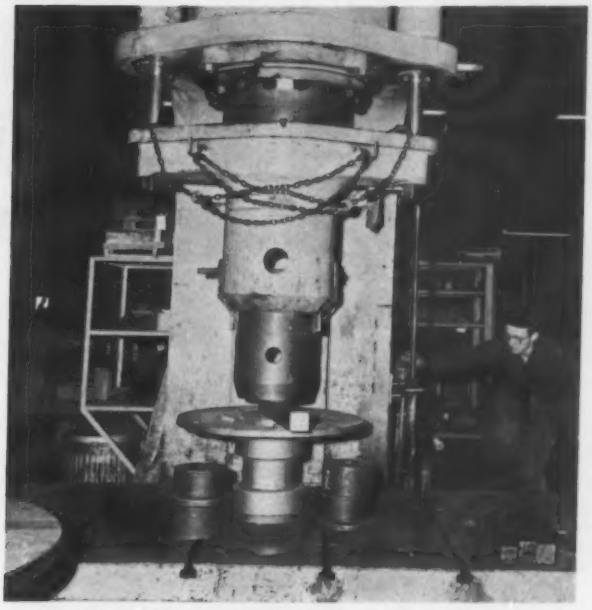

Fig. 31 — 500 ton straightening press.

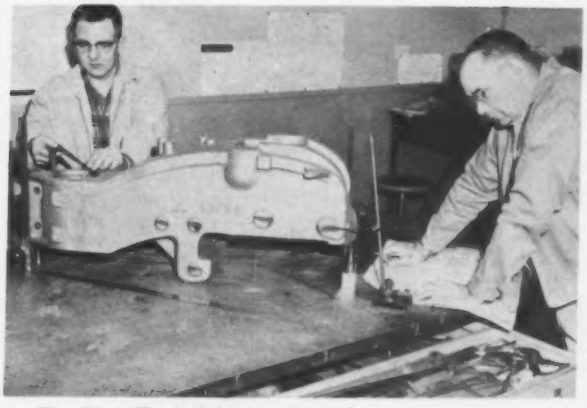

Fig. 32 — Typical layout inspection.

Fig. 33 — Final template inspection.

MOLD VARIABLES INFLUENCE ON FLUIDITY OF ALUMINUM

Doubling casting ductility by fluidity control

by M. C. Flemings, F. R. Mollard and H. F. Taylor

ABSTRACT

Results are presented of a study of the influence of various molding materials on the fluidity of aluminum-4.5 per cent copper alloy. Molding materials studied include green sand with various water contents and additives, core sands (bonded with linseed oil and phenol-formaldehyde), CO_2 sand and zircon sand. Effects of variables such as sand grain size were also studied. Results indicate significant influences of the molding materials on fluidity. For example, fluidity is 20 to 27 per cent less in core sands than in green sand, and 22 to 55 per cent less in zircon sand than in green sand. Data obtained are analyzed in detail.

Fluidity improvement due to mold coatings such as hexachloroethane is shown to result from reduction in the mold-metal heat transfer coefficient. These mold coatings are effective in improving fluidity of a wide range of metals and alloys in sand molds (not just aluminum alloys). Use of mold coatings can result in significantly improved properties in aluminum castings, by permitting substantially reduced pouring temperatures. For example, in an aluminum-4.5 per cent copper alloy test casting, coatings permitted lowering the pouring temperature 100 F. As a result, elongation doubled (increased from 4 per cent to 8 per cent) with a simultaneous increase in tensile strength.

INTRODUCTION

Work conducted during the third year of a research program on fluidity of aluminum alloys conducted at Massachusetts Institute of Technology, sponsored by the U.S. Army Ordnance Department through Pitman-Dunn Laboratory, Frankford Arsenal is described. Publications and reports issued earlier have described work conducted to date on fundamental and applied aspects of the program.[1,2]

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Much of the work conducted has been on basic investigations of heat and fluid flow, and of solidification in fluidity test channels. In addition, an applied phase of the study was the investigation of fluidity in sand molds, and of the improvements in fluidity that could be obtained through use of mold coatings.[2,4] Work reported herein is a continuation of that portion of the study concerned with fluidity in sand molds. It is concerned primarily with (1) influence of various molding materials on fluidity of aluminum alloys and (2) influence of mold coatings on mechanical properties of thin aluminum castings.

MOLD VARIABLES INFLUENCE ON ALUMINUM-4.5 PER CENT COPPER ALLOY FLUIDITY

Test Apparatus and General Procedure

This study was conducted using the double spiral sand mold test developed and described in detail earlier.[2-4] Figures 1 and 2 illustrate the test casting and mold design. Essential features of the test are:

1) An overflow pouring basin to maintain constant metal head (pressure) during pouring.
2) A tapered sprue and sprue well to minimize turbulence and dross formation.
3) A large runner and bottom gated spiral, to insure that no metal enters the test section until full pressure (metal head) is developed in the pouring basin.
4) A screen to filter entrapped dross.
5) Two test spirals.

The two spirals in a single mold permit study of different mold (and mold coating) variables. For example, one spiral can be rammed in green sand and the other in CO_2 sand to determine relative

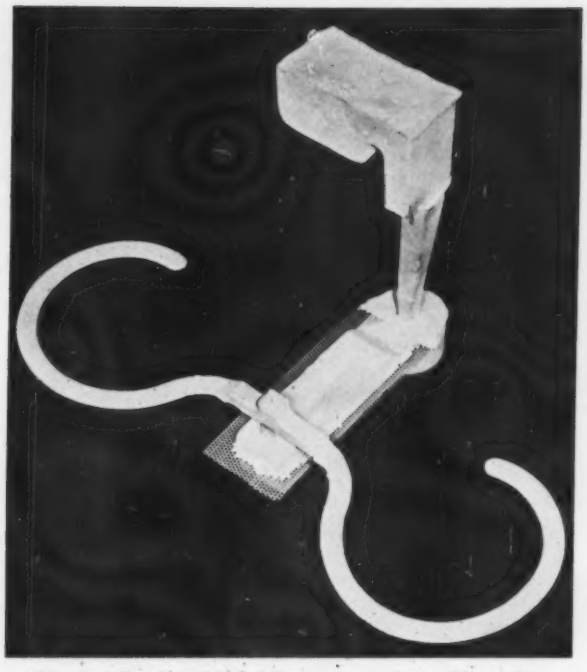

Fig. 1 — Sand mold fluidity test casting with gating system.

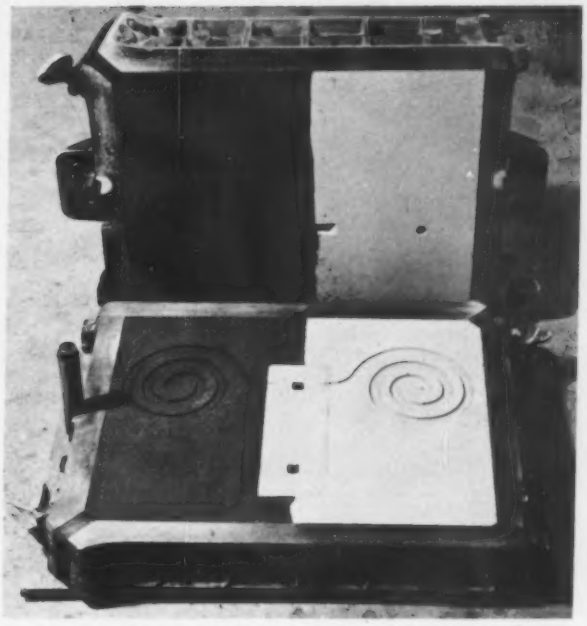

Fig. 3 — Cope and drag of sand mold fluidity test casting, showing technique used to compare fluidity in green sand (left) with that in CO_2 sand (right).

fluidities in these two molding media. Figure 3 illustrates such an arrangement.

The general procedure used for testing mold variables was to produce six test molds for each trial run. One spiral in each test mold was faced (covered to a depth of ½-in.) with the molding media to be studied, and the other spiral was faced in a standard foundry sand as a control piece (110 AFS, clay bonded green sand, Mix A, Table 1). The standard foundry sand was then used as backing sand for the entire mold. Fluidity tests are of such short duration (metal flows in the spiral for only about one sec) that ½-in. of sand is more than adequate as an "infinite" mold. For some tests, minor modifications of the above molding procedure were employed and these are noted where used.

Each set of fluidity tests was conducted as described earlier,[2,4] except that in this work grain refined metal was used to simulate commercial practice. In previous cases the metal was not grain refined. A gas fired furnace was used to melt metal of nominal composition 4.5 per cent copper, 0.14 per cent titanium, balance aluminum. Charge materials were aluminum ingot (99.9 per cent), aluminum-copper master alloy (50 per cent Cu), aluminum-titanium master alloy (6 per cent Ti) and revert (pigged

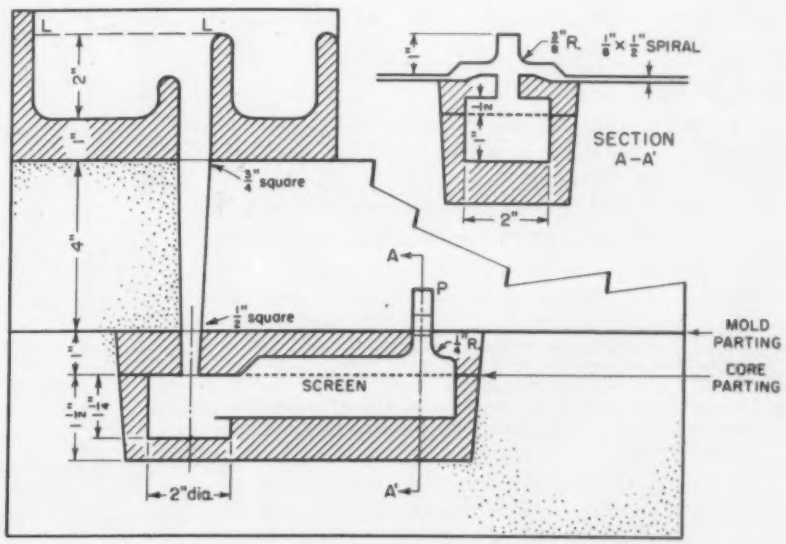

Fig. 2 — Schematic diagram of gating system for sand mold fluidity test.

TABLE 1 — COMPOSITION OF SAND MIXES TESTED

Composition	Pounds
Mix A (Standard green sand)	
Silica sand (110 AFS)	100
Southern bentonite	5.0
Cereal	0.75
Water	3.5
Mix B (Zircon green sand)	
Zircon sand (110 AFS)	100
Southern bentonite	2.5
Cereal	0.40
Water	1.75
NOTE: On a volumetric basis, this sand has approximately the same quantity of additives as Mix A.	
Mix C (Fine green sand)	
Silica sand (140 AFS)	100
Southern bentonite	5.0
Cereal	0.75
Water	3.5
Mix D (Coarse green sand)	
Silica sand (30 AFS)	100
Southern bentonite	5.0
Cereal	0.75
Water	3.5
Mix E	
Silica sand (110 AFS)	100
Proprietary sodium silicate binder	3.0
Mix F	
Silica sand (110 AFS)	75
Silica sand (80 AFS)	25
Proprietary sodium silicate binder	3.0
Mix G	
Silica sand (110 AFS)	100
Linseed oil	2.8
Cereal	1.5
Water	5.0
Baked at 400 F, 3 - 4 hr	
Mix H	
Silica sand (110 AFS)	100
Proprietary phenol-formaldehyde resin binder	1.0
Cereal	1.5
Water	4.0
Baked at 400 F, 3 - 4 hr	

aluminum from gates and risers of previous test castings which were analyzed before use) in quantities up to 75 per cent of the total charge. Chemical analyses were made on most heats which proved to be 4.65 per cent ± 0.20 per cent copper and 0.13 to 0.14 per cent titanium.

Dry Nitrogen Degassing

Each melt was degassed by bubbling dry nitrogen through the metal for at least 10 min at 1300-1350 F (704-732 C) while the metal was in the furnace. Melts were then tapped at 1400 F (760 C) and checked for gas with the reduced pressure tester. If any gas was found to be present, the degassing operation was repeated. Samples were taken from each heat for chemical analysis. After tapping, all molds were poured consecutively from the same crucible. Care was taken to insure accurate pouring temperatures.

Since pouring temperature is of great importance in determining metal fluidity, it is necessary to measure temperatures precisely. In these experiments, a chromel-alumel thermocouple, enclosed in an iron protection tube, was immersed in the crucible at the time of pouring. Melt contamination was prevented by coating the iron tube with silica-bentonite wash. The temperature of the melt at the instant of pouring was indicated on an electronic recorder with an external cold junction (ice water).

After shakeout, the test spirals were measured by comparison with a reference spiral graduated every 0.2 in. Readings were made at the extreme tip of the spiral and, although the spiral tip was slightly rounded, the readings may be considered accurate to ± 0.1 in. The shape of the tip was uniform in all the spirals, and there were no irregular surface protrusions.

Thickness of each spiral was measured carefully to determine if there was any accidental variation of thickness, but accuracy was maintained at ± 0.005 in. A few spirals exceeded this tolerance and were discarded. Thickness measurements were taken every 2 in. along the axis of the spirals, and a trend was noted for them to be slightly undersize at mid-length and oversize near the tip. The extreme tip was again undersize and smooth, due to surface tension and film effect which prevented complete filling of the mold. Similar results have been reported previously.[2] Aver-

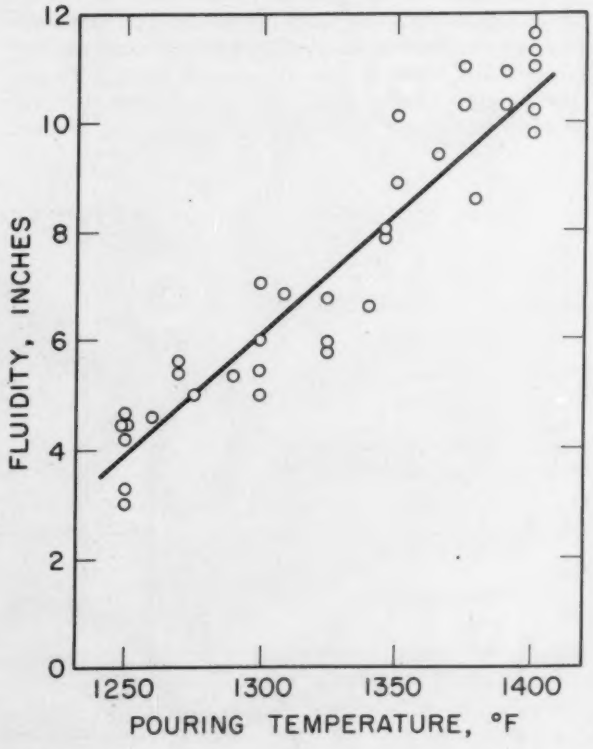

Fig. 4 — Fluidity vs. pouring temperature for grain refined aluminum-4.5 per cent copper alloy. Data are from control spirals of present work, representing 8 heats. Control spiral was green sand, 110 AFS fineness number. Grain refining was by addition of 0.15 per cent titanium.

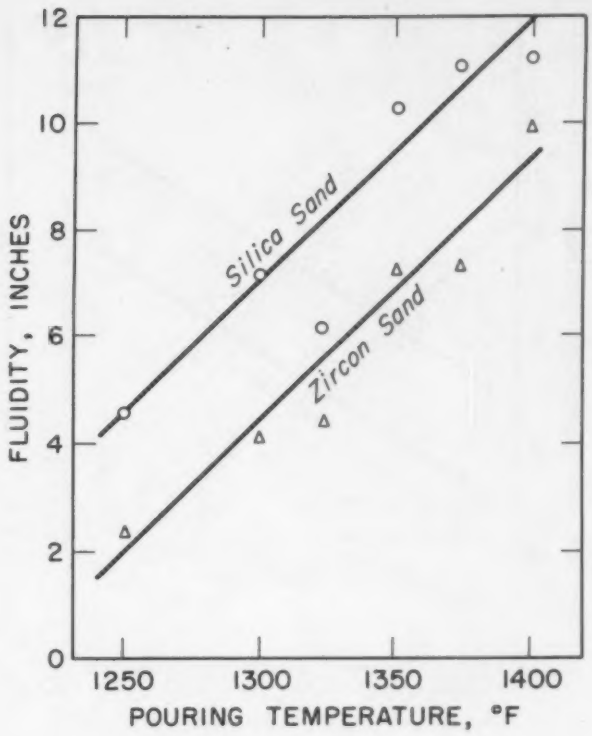

Fig. 5 — Fluidity of aluminum-4.5 per cent copper alloy in silica sand and zircon sand. Both sands were bentonite bonded, green and of approximately 110 AFS fineness number.

age thickness of all test castings produced was 0.123 in. ± 0.005 in. (except where otherwise noted).

Figure 4 summarizes data obtained from the control spiral of eight different heats. The data fall generally within ± one in. of a "standard" curve, with only 4 points falling outside this band. The standard curve for this study falls slightly below that reported earlier,[2,4] probably because grain refined metal was used for the studies described but not for those reported previously. It is to be expected that grain refinement would reduce fluidity in this test, as it does in the vacuum fluidity test.[3]

Fluidity in a Chilling Sand

In order to determine if molds made of a "chilling" sand (sand with a high thermal diffusivity) would reduce fluidity significantly, tests were made using zircon and regular silica sand in undried (green) sand molds. The zircon sand was similar in grain distribution to the 110 AFS standard silica sand, Table 2. Since the density of zircon sand is approximately twice that of washed silica sand, the amount of additives (clay, cereal, water) mixed with zircon sand was only half as much by weight as the amount mixed with the standard sand. Thus, both sands had approximately equal volumetric compositions. Mix B, Table 1, is the mixture of zircon sand used.

Figure 5 is a comparison of the effects of zircon and silica sand molds on fluidity. Zircon sand lowers fluidity significantly (approximately 2.5 in. at all temperatures). Spirals cast in the zircon sand showed no apparent difference from those cast in silica sand (as regards surface finish, spiral thickness, etc.), and it appears certain that the lower fluidity in zircon sand is directly attributed to the greater chilling power* of this material.

Sand Grain Size Effect on Fluidity

The influence of sand grain size on fluidity was determined using two different sands in each test mold.

TABLE 2 — GRAIN SIZE DISTRIBUTION OF SANDS TESTED

U.S. Sieve Number	Weight Retained				
	Silica sand (110 AFS)	Silica sand (110 AFS + 80 AFS)	Zircon sand (110 AFS)	Fine silica sand (140 AFS)	Coarse silica sand (30 AFS)
+20					2
+30					57
+40					40
+50		1			
+70	5	17		1	
+100	29	40	11	13	
+140	34	23	66	29	
+200	18	11	19	31	
+270	6	3	1	17	
Pan	5	3	—	8	
Total (Grams)	97	98	97	99	99

To emphasize possible effects, the standard 110 AFS sand was not employed, and in its place a still finer sand (Mix C, Table 1) was used on one side of the mold. The spiral on the other side of the mold was molded in a coarse sand (30 AFS, Mix D).

It was found that fluidity in the fine sand was lower than in the coarse sand. This was contrary to preliminary expectations, since the chilling power of coarse sand was thought to be somewhat greater than that of fine sand.[5,6] The explanation for results obtained (Fig. 6) lies in the fact that significant metal penetration was obtained in the coarse sand spirals. The penetration amounted to as much as 0.025 in. on each face of the spiral (approximately one grain diameter for No. 30 AFS sand). This amounted to approximately 10 per cent by weight.

*"Chilling power" of molding sands can be expressed quantitatively as the square root of the product of thermal conductivity, density and specific heat of the bulk sand. Chilling power of zircon sand is approximately 50 per cent greater than that of silica sand. Under conditions ordinarily encountered in solidification of simple sand castings (negligible resistances to heat flow in the metal and at metal-mold interface), the above means that in a given time zircon sand will extract 50 per cent more heat from a solidifying casting than will silica sand. It means, further, that a simple casting will solidify in zircon sand in less than half the time required in silica sand.

In the case of a fluidity test casting, solidification time is so short that heat flow resistance at the metal-mold interface cannot be neglected.[7] Here, zircon sand will not exert the full influence calculated, but will nonetheless extract heat more rapidly than silica sand.

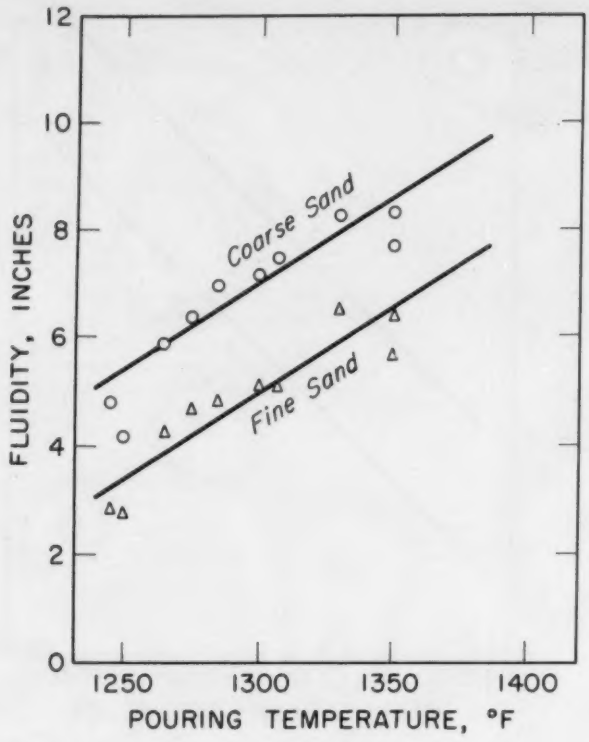

Fig. 6 — Fluidity of aluminum-4.5 per cent copper alloy in coarse (30 AFS) and fine (140 AFS) silica sand, clay bonded, green. Data from two heats.

The added heat of fusion that must be extracted to solidify an extra 10 per cent of metal can readily account for the increase in fluidity observed. As concerns the effect of grain size on thermal diffusivity, this effect would be expected to be small particularly at temperatures of interest in aluminum founding.[8] Even at steel temperatures, differences in grain size per se have not been found to affect fluidity.[9]

While the higher permeability of coarse sand is sometimes considered to promote fluidity, this does not appear to be a factor in these tests. Vents (½-in. diameter) were cut at the extreme ends of all spirals in this study to avoid any danger of back pressure. Also, in order to check if back pressure was significant, a series of tests were conducted with and without vents (standard 110 AFS green sand). No effect of venting on fluidity was found.

Moisture Content

To determine the effect of moisture content on fluidity in clay bonded sand, a series of molds was poured in one heat in which the first and last molds poured had been made of standard green sand (containing 3.5 per cent water). Intermediate molds were of the same sand but had been baked 3 - 4 hr at 400 F (204 C) and allowed to cool. Baked molds gave the same results as green sand molds (Fig. 7), and it may be assumed that fluidity in clay bonded sands is not influenced by moisture content at least in amounts up to 3.5 per cent.

New Versus Used Sand; Effects of Additives

It was felt that carbonaceous residues and/or other changes in molding sands as a result of repeated use might have some effect on fluidity. Hence, tests were conducted with the standard 110 AFS green sand in the new and re-used condition, with moisture content of both sands held at 3.5 per cent. Results of fluidity tests showed no measurable effects.

Fluidity was next compared in two green sand mixes which were standard, except that one mix contained 0.75 per cent cereal. Cereal proved to have no effect on fluidity.

To determine if larger amounts of organic material might affect fluidity, 10 per cent sawdust was added to the molding sand. Even with this large amount of

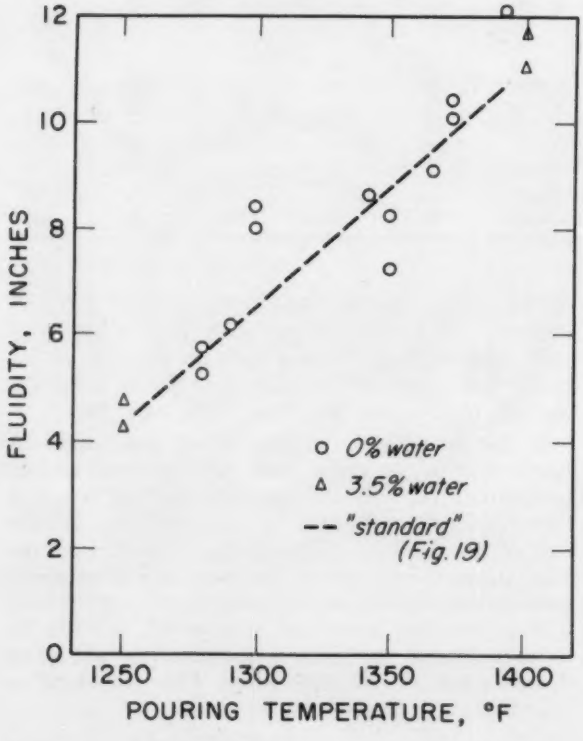

Fig. 7 — Fluidity of aluminum-4.5 per cent copper alloy in clay bonded silica sand, showing fluidity is the sand in dried molds (0 per cent water) as in green molds (3.5 per cent water). Sands were 110 AFS fineness number.

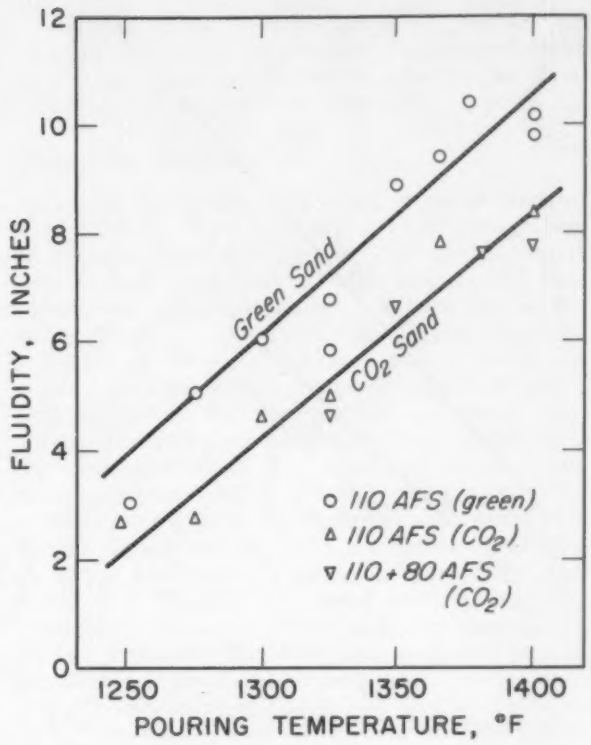

Fig. 8 — Fluidity of aluminum-4.5 per cent copper alloy in sodium silicate bonded (CO_2) sand and in green clay bonded sand. Data from two heats. Green sand was 110 AFS fineness number.

additive, only relatively small improvement (10 to 13 per cent) was detected.

Binder Effect on Fluidity

Sodium Silicate. Two heats were made to compare fluidity in sand molds bonded with sodium silicate to that of regular clay bonded green sand. The standard 110 AFS green sand (Mix A) was used as control, and two sodium silicate bonded mixes were tested:

1) A mix based on 100 per cent 110 AFS sand (Mix E).
2) A mix based on 75 per cent 110 AFS sand and 25 per cent 80 AFS (Mix F).

Results of these tests (Fig. 8) show that fluidity in the sodium silicate (so-called CO_2) bonded sands is somewhat less than in green sand. Fluidity was the same in the two sodium silicate bonded mixes, indicating again that sand grain size had no effect on fluidity. In this test, spiral surface finish, weight, etc. were the same for castings produced in different sands, and so metal penetration did not influence results as it had in the tests summarized in Fig. 6.

Linseed Oil. Results of tests to determine fluidity in linseed oil bonded (dry sand) molds are summarized in Fig. 9. Molds poured at the highest and lowest temperatures were control molds, made with standard 110 AFS green sand. Molds poured at intermediate temperatures were composite molds, consisting of linseed oil bonded sand facing (Mix G), on one spiral, and standard 110 AFS sand on the other spiral. These molds were baked at 400 F (204 C) for 3-4 hr and cooled to room temperature before pouring. Fluidity in the linseed oil bonded sand was lower than in the green sand.

Phenol Formaldehyde. Fluidity in molds bonded with phenol formaldehyde, like that in other core sands, was lower than in green sand, Fig. 10. In this series of tests, the molds poured at the highest and lowest pouring temperatures were of the standard 110 AFS green sand (Mix A). Molds at intermediate temperatures were faced with phenol formaldehyde bonded sand (Mix H). These were baked at 400 F (204 C) for 3-4 hr and cooled to room temperature before pouring.

Binders Effect on Fluidity Discussion. There appears to be no simple explanation why fluidity in

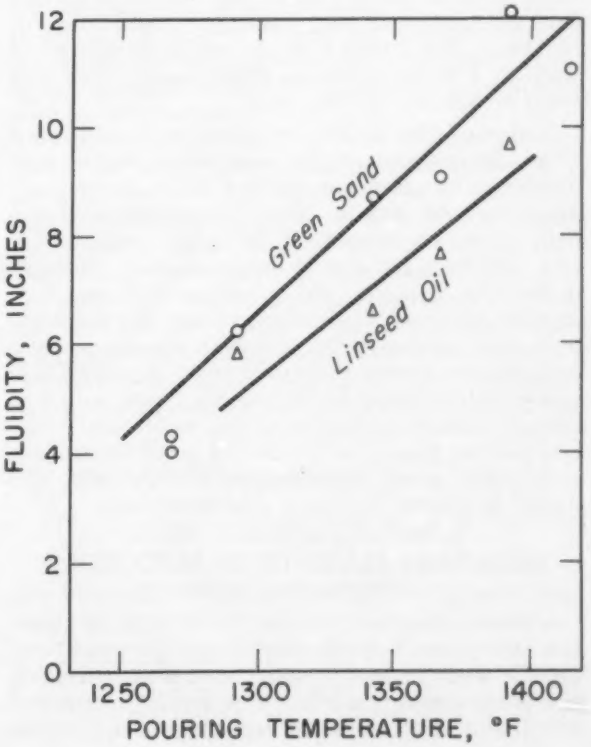

Fig. 9 — Fluidity of aluminum-4.5 per cent copper alloy in clay bonded green sand. Both sands were 110 AFS fineness number.

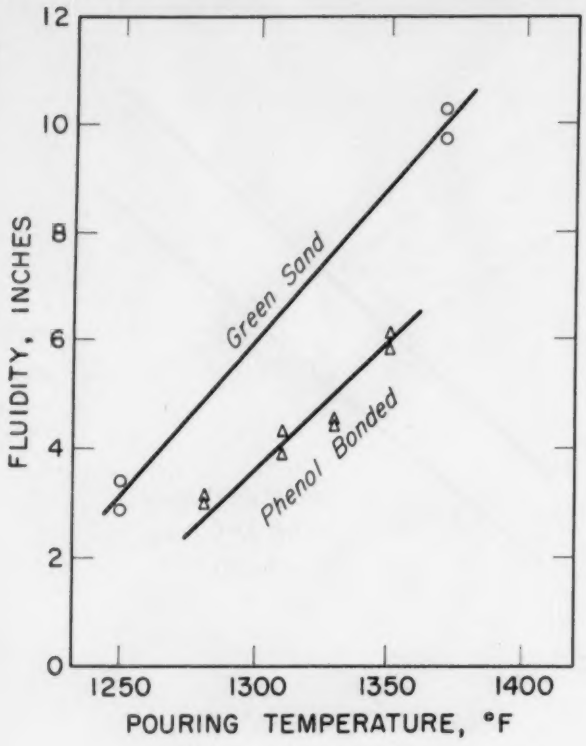

Fig. 10 — Fluidity of aluminum-4.5 per cent copper alloy in phenol-formaldehyde bonded sand and clay bonded green sand. Both sands were 110 AFS fineness number.

various core sands (including those bonded with sodium silicate, linseed oil and phenol formaldehyde) is less than fluidity in green clay bonded sand. Differences in moisture content alone cannot account for the results obtained, since it was shown that moisture content has no effect on fluidity in clay bonded molds. Factors such as changes in surface tension or surface films are unlikely to have influenced results, and surface finish and thickness of the spirals were checked carefully with no significant differences detected as a result of different binders used.

It appears that fluidity in green sand molds must be greater than that in core sand molds because heat transfer is somehow less effective in the green sand. This could be because of (1) lower thermal Diffusivity in the green sand, or (2) higher contact resistance due to a gas film at the metal-mold interface in the case of green sand. There is little reason to suppose that green sand possesses lower thermal diffusivity than do core sands, and experimental evidence indicates the reverse to be true.[10, 11] A more likely reason for the higher fluidity in green sand is that in thermal contact resistance at the mold-metal interface may be greater in the case of green sand. However, there is no apparent explanation why this should be so.

ALUMINUM FLUIDITY IN SAND MOLD QUANTITATIVE ASPECTS

A mathematical analysis for the fluidity of aluminum alloys has been developed and presented elsewhere.[3] This analysis is based on a model of metal flow and solidification behavior in fluidity spirals that is in accord with current understanding of the process, and can be applied with relative ease to solution of a wide range of problems of practical interest. Some results of this analysis are considered herein, as they apply to, and aid in, understanding experimental observations on fluidity in sand molds.

Specifically, the analysis referred to above applies to fluidity tests on mushy freezing alloys, such as 195 alloy, in which:

1) Solid particles form during flow in a fluidity spiral and travel downstream with the liquid.
2) Flow stops when the mean solid concentration reaches a certain value (critical solid concentration).
3) Flow velocity is essentially constant until flow stops.

The analysis shows, quantitatively, that these factors are important in determining fluidity:

1) Test variables, such as geometry of the flow channel and effective pressure (metal head) at the spiral entrance.
2) Mold variables including mold temperature and thermal diffusivity of the mold.
3) Metal-mold variables, specifically, thermal contact resistance between metal and mold.
4) Metal variables including superheat, amount of solid required to stop flow (critical solid concentration), and heat of fusion of the solidifying metal.

For fluidity tests of the kind usually employed (and for most sand castings) factors such as surface tension, surface films or viscosity may be neglected.

In addition to delineating many factors that are known by intuition or experiment to affect fluidity in sand molds, the analysis shows that two less well understood factors can have an important effect. These are (1) changes in critical solid concentration and (2) changes in mold-metal (thermal) contact resistance.

In most fluidity spirals (and in most sand castings) effective metal head is low. For example, in the sand spiral used in this work the metal head over the spiral was 7 in.; however, due to friction losses in the runner system the "effective" metal head, in terms of pressure at the spiral entrance, was somewhat less than 2 in. Under these conditions a small amount of solidification near the tip of the flowing stream is sufficient to stop flow – about 5 per cent solid suffices. At higher pressures (not usually obtained in sand casting) substantially more solidification can occur before flow ceases.

Thermal diffusivity (chilling power) of molds is

known to affect fluidity by altering the rate of heat extraction. In addition, thermal contact resistance at the mold-metal interface must also be considered, and analysis shows it to be a significant factor. This is different from the case of solidification of relatively large castings where (because of the much longer times involved) mold-metal contact resistance can be neglected.

Heat Transfer Coefficient

Analysis of data obtained in this work, and earlier,[3] indicates the coefficient of heat transfer at the mold-metal interface in sand molds is about 0.05 cal/cm² sec° C, and shows this value to be significant in determining total flow.

As reported earlier, certain mold coatings, such as hexachloroethane and carbon black increase fluidity in green sand molds by as much as a factor of three.[2, 4] On the other hand, the use of certain core sands instead of green sand result in decreases of fluidity from 20 to 40 per cent. Changes in the heat transfer coefficient that would account for such changes in fluidity were calculated, and are shown in Table 3. Critical solid concentration was assumed to be 5 per cent.

TABLE 3 — HEAT TRANSFER COEFFICIENT AT MOLD-METAL INTERFACE EFFECT ON FLUIDITY IN SAND MOLDS

Heat transfer coefficient h, cal/cm² sec° C	Fluidity at 1350 F, L_f, in.	Change in fluidity,* %
0.015	30	+200
0.053	10	0
0.071	8	−20
0.110	6	−40

*Compared to fluidity at h = 0.053; this is the value obtained for uncoated green sand molds.

It is of interest to note that the heat transfer coefficient need be changed for only an extremely short time to influence fluidity. For example, in a typical test in a fluidity spiral, metal velocity (V) is 80 cm/sec and the choking zone (ΔX) is one cm. The average time the tip of the metal is in contact with any one portion of the mold is $1/80 = 0.018$ sec.

To substantiate that mold coatings did improve fluidity by changing heat transfer and not by some other mechanism, a study was made of the effect of mold coatings on flow velocity in the sand mold fluidity test. The reason for studying flow velocity to determine the mechanism of fluidity improvement is that analysis[1,2] and intuition indicate:

1) If a mold coating improves fluidity by changing factors such as surface tension, oxide films, etc., this improvement (from a fluid flow standpoint) should be the same as would be achieved by an increase in pressure head. This, flow velocity (particularly initial flow velocity) would be markedly increased. Duration of flow (fluid life) would be increased only slightly, or even decreased, depending on alloy content, superheat, etc.
2) If a mold coating improves fluidity by changing the rate (or mode) of solidification, fluid flow variables in the early portion of the test will remain unchanged. In this case, the initial velocity of the stream should not be affected, but fluid life should be increased markedly.

Fluid Flow Determination

Flow velocities were determined in the green sand mold fluidity spirals through use of motion picture photography (64 frames/sec). The double spiral (Fig. 3) had been designed especially so the flow channel was wholly in the drag (bottom half of the mold). This allowed substitution of glass plates for a portion of the sand cope (top half of mold). In practice, two plates, each approximately 8 in. square were molded so they covered the two spirals completely. After the cope was rammed and turned over, the sand covering the plates was cut away so the two spirals were visible.

Before closing the mold, one spiral was treated with a mold coating and the other left untreated. During the actual fluidity test, a motion picture camera was placed so it would record metal flow into the two spirals simultaneously. Occasionally the glass plates cracked, but only after flow was completed (actual flow time in all cases was one sec or less).

In all tests using the technique described above, initial flow velocity was the same in the coated and uncoated spirals. Therefore, it can be concluded that the hexachloroethane changes heat transfer and not surface phenomena such as surface oxide films, surface tension, etc. Figure 11 shows a plot of distance versus time (in the spiral test) for an aluminum-4.5 per cent copper alloy poured at 1325 F (719 C). In three other tests similar results were obtained. In all cases, initial velocity of the metal (initial slope of the curve of Fig. 11) was constant at 30 - 35 in./sec regardless of pouring temperature. In other words, the coated spiral flowed not faster but longer, and therefore farther. A similar test conducted with a mold coating of amorphous carbon also showed improvement in fluidity with no effect on flow velocity.

Further confirmation that mold coatings improve fluidity by changing the heat transfer coefficient is given by the fact that hexachloroethane mold coatings have resulted in improved fluidity of all metals and alloys tested to date. It appears unlikely that the coating could effect improvement in all alloys by any other mechanism than changing the heat transfer coefficient. Table 4 lists results obtained for a series of ferrous and nonferrous alloys, including two aluminum alloys, a magnesium alloy, two copper base alloys, a low alloy steel and a stainless steel.

MOLD TREATMENT EFFECT ON MECHANICAL PROPERTIES OF THIN WALLED CASTINGS

One practical result of work conducted earlier in this program[2,4] was the development of mold coatings for improving fluidity of aluminum alloys in practice, and the establishment by various tests that mold coatings had a strong influence on fluidity. Many foundries are now using these coatings, and as a result it is of practical interest to determine what

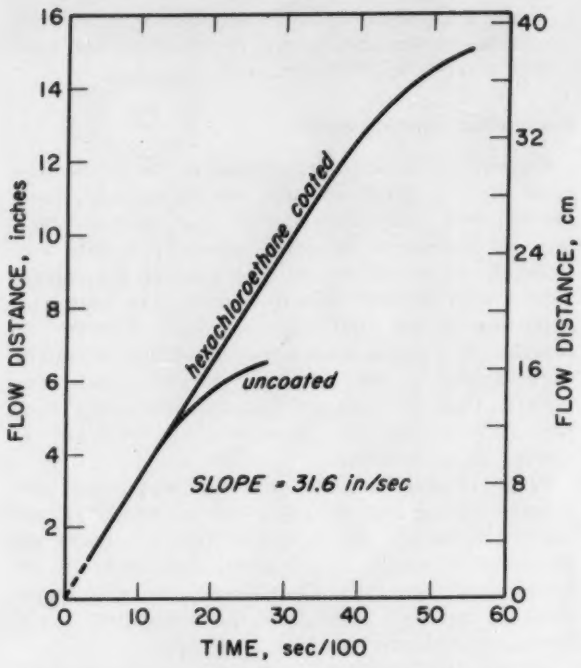

Fig. 11 — Distance vs. time for hexachloroethane-coated and uncoated spiral. Aluminum-4.5 per cent copper alloy. Pouring temperature 1325 F.

effect, if any, the coatings have on mechanical properties of sand castings.

To determine the above, a test casting was constructed with two plates mounted on opposite sides of a runner, each plate being 5 x 5 x ⅛-in. thick (Fig. 12). To determine the effect of mold coatings, the mold cavity of one plate was coated and the other left uncoated. A series of castings was then produced at different pouring temperatures using

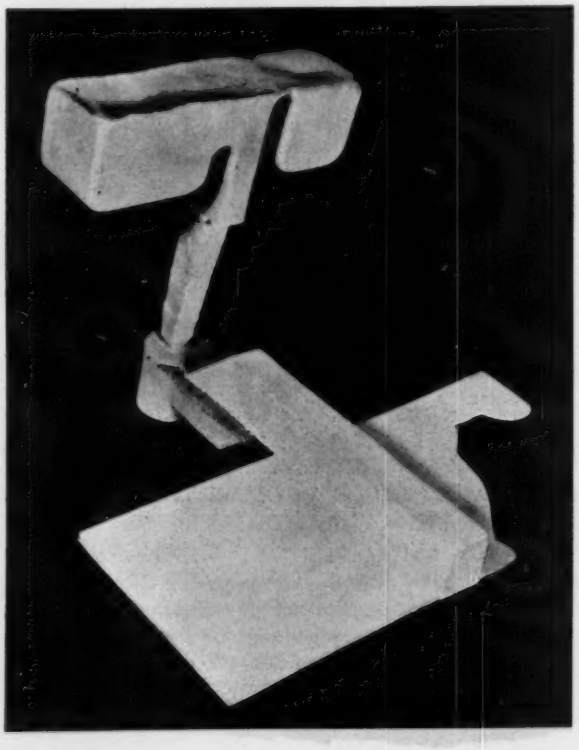

Fig. 12 — Test plate used for studying effect of mold coatings on soundness and mechanical properties of test plates. Identical plates on each side of the runner are 5 x 5 x ⅛-in. thick. In test casting, brown hexachloroethane mold coating promoted complete filling of the left plate. The plate on the right is not filled. No venting was employed.

TABLE 4 — HEXACHLOROETHANE EFFECT ON FLUIDITY OF SOME COMMERCIAL NONFERROUS AND FERROUS ALLOYS

Alloy	Pouring temp., F	Fluidity control spiral, in.	Fluidity coated spiral, in.	Fluidity increase due to coating, in.	Increase due to coating, %
Aluminum Alloys					
195 Al-4.5 Cu	1318	6.3	17.9	11.6	184
	1249	3.8	11.0	7.2	190
356 Al-7 Si-0.3 Mg	1318	11.9	22.1	10.2	86
	1246	7.2	14.1	6.9	96
Magnesium Alloy					
AZ91C Mg-8.7 Al -0.72 Zn-0.15 Mn	1300	12.3	23.5	11.2	91
Copper-Base Alloys					
Manganese-Bronze 58.2 Cu-39 Zn 1.4 Fe-1 Sn-0.1 Mn	1750	4.8	10.7	5.9	122
85-5-5-5 85 Cu-5 Sn -5 Pb-5 Zn	2000	3.5	5.7-7.7*	2.2-4.2	63-125*
Ferrous Alloys					
4340 Steel 0.40 C-1.75 Ni 0.80 Cr-0.25 Mo	2820	3.3	5.0-8.4*	1.7-5.1	56-154*
CA-40 (420) Stainless Steel	3100	11.0	12.2-13.8	1.2-2.8	11-25
0.20 C-13.4 Cr 0.40 Mn -0.30 Si	3000	9.3	11.8-12.6*	2.5-3.3	27-35

*The smaller figure refers to the length of spiral in which the metal completely filled the mold cavity. The larger figure gives the maximum length to which any metal flowed in the spiral.

different coatings. These were radiographed and heat treated, and mechanical properties were determined by cutting test bars from the castings.

Castings Poured; Coatings Effect on Fluidity and X-ray Quality

Two coatings were examined (hexachloroethane and carbon black), and the alloy poured was aluminum-4.5 per cent copper with 0.18 per cent titanium added as a grain refiner. Melting, degassing and temperature measurements were as previously described.[2] Molds were hand-rammed in 12 x 12 in. flasks, using bentonite bonded green sand of 110 AFS fineness number. Hexachloroethane was sprayed from an ether solution to a thickness of about 0.004 in. Carbon black was applied with a smoking acetylene torch.

Eleven castings were poured at temperatures ranging from 1305 F to 1190 F (707 to 593 C). At temperatures below 1272-1300 F (688-704 C) misruns were apparent on the uncoated plates. At 1300 F (704 C) radiography indicated the plates did not completely fill, and so temperatures higher than 1300 F (704 C) would be necessary in practice to produce a sound casting if no coating were used. The hexachloroethane and carbon black coatings permitted filling the plates completely (visually and radiographically) at pouring temperatures as low as 1200 F (649 C). Both coatings improved fluidity to about the same extent, and neither had any deleterious effects on X-ray soundness or surface quality of the cast plates. Figure 13 is a sketch of three typical plates produced.

Coatings Effect on Mechanical Properties

Flat test bars (0.100 in. thick x 0.500 in. x 1.00 in. gage) were cut from the plates in two locations. One location was adjacent to the runner, and the other was one in. from the outer edge of the plates (parallel to the runner). All test bars were cut from areas of plates that were radiographically sound, and were heat-treated:

Solution treatment 960 F (516 C), 16 hr, water quench.
Hold at room temperature 24 hr.
Age at 310 F (154 C) for 15 hr.

Location of the test bars had only a relatively small effect on mechanical properties. Bars farthest from the runner had slightly higher properties, but the average increase was only about 1.4 per cent in elongation and 2000 psi in ultimate tensile strength. The coatings had little or no effect, per se, on mechanical properties. Properties were the same at a given pouring temperature regardless of whether molds were coated or not (Figs. 14, 15). However, the coatings had a major beneficial effect on properties indirectly by permitting substantial reductions in pouring temperature.

For example, castings poured in coated molds at 1200 F (648 C) possessed mechanical properties of the order of 55,000 psi ultimate tensile strength, 36,000 psi yield strength and 8-10 per cent elongation. Without the mold coating, temperatures in excess of 1300 F (704 C) are essential for mold filling, and resulting mechanical properties are decreased

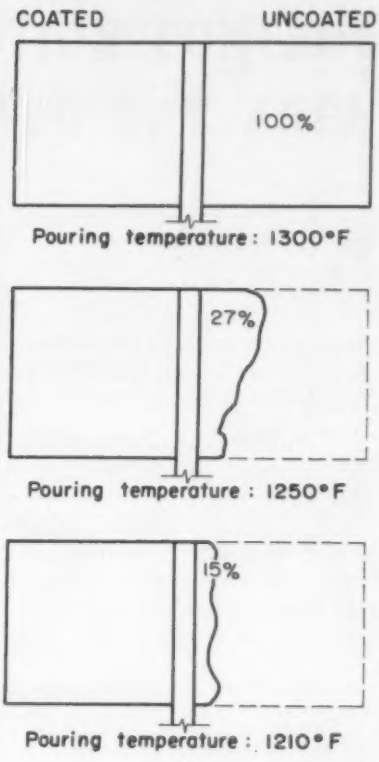

Fig. 13 — Appearance of typical test plate castings. Left side coated with carbon black; right side uncoated.

to less than 50,000 psi tensile strength, 36,000 psi yield strength and 4 per cent elongation.

The above results are readily explainable in view of the concepts presented previously. Briefly, these coatings affect heat transfer conditions only during the first small fraction of a second. Afterward (during nearly all the solidification process) their effect on heat transfer is negligible. Thus, the coatings act to slow heat transfer at a desirable time (during filling of the mold), but later do not prevent the rapid heat extraction necessary to produce a sound, strong casting.

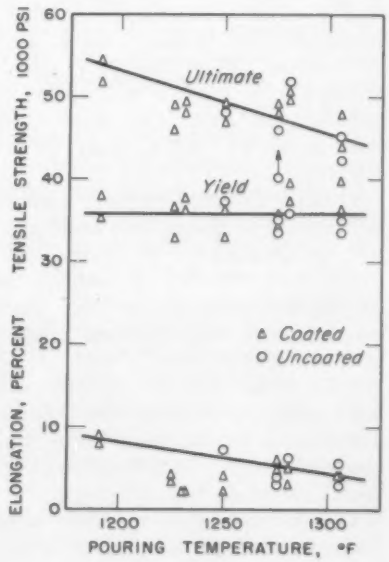

Fig. 14 — Hexachloroethane mold coating effect on mechanical properties of test plate castings (from two different heats).

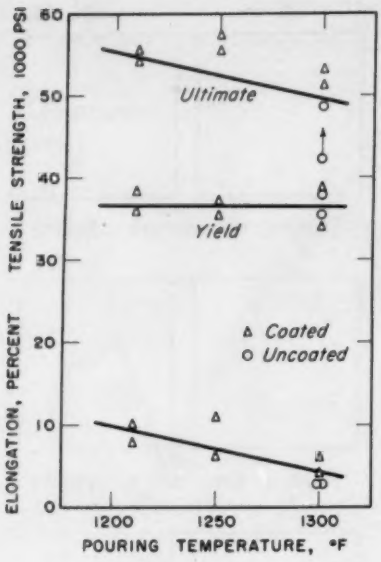

Fig. 15 — Carbon black mold coating effect on mechanical properties of test plate castings (from one heat).

CONCLUSIONS

Fluidity of Al - 4½ - per cent copper alloy poured in zircon sand is lower than in silica sand. Reductions found were 55 per cent at 1250 F (677 C) and 22 per cent at 1400 F (760 C). The lower fluidity in zircon sand is primarily due to the greater heat diffusivity of zircon as compared to silica. Variations in grain size affect fluidity only when the grains become sufficiently coarse that rough surfaces and significant penetration result. The extra effective thickness of spirals in very coarse sand increases apparent fluidity by providing more metal which takes longer to freeze.

Moisture content of clay bonded sand (up to 3.5 per cent) has no effect on fluidity. Cereal (up to 0.75 per cent) has no effect on fluidity in green clay bonded sand. Fluidity in re-used clay bonded green sand is the same as fluidity in new sand. Ten per cent sawdust added to green clay bonded sand increases fluidity 10 per cent at 1250 F (677 C) and 13 per cent at 1400 F (760 C). Fluidity in molding sand bonded with sodium silicate is less than in green clay bonded sand. The decrease found was 45 per cent at 1250 F (677 C) and 20 per cent at 1400 F (760 C).

Fluidity in molding sand bonded with linseed oil is less than in green, clay bonded sand. The decrease is approximately 20 per cent at 1250-1400 F (677-760 C). Fluidity in molding sands bonded with phenol-formaldehyde is less than in green, clay bonded sand. The decrease is approximately 50 per cent at 1275 F (692 C) and 27 per cent at 1375 F (746 C). The fluidity in core sands (as compared with green sand) is decreased because the core sands are able to extract heat more rapidly, probably because of a higher heat transfer coefficient at the mold-metal interface.

Comparison of theory with experiment shows that improvements in fluidity obtained by use of mold coatings such as hexachloroethane or carbon black are due to reduction of the heat transfer coefficient at the metal-mold interface, rather than to any effect of these coatings on surface tension or surface oxide films. Differences in fluidity in silica sand and zircon sand can be largely accounted for by the different thermal properties of these materials.

Hexachloroethane mold coatings are effective in improving fluidity of a wide range of metals and alloys (not just aluminum alloys). Significant improvement has been found in all alloys tested, including magnesium alloys, manganese-bronze, 85-5-5-5 copper base alloy, low alloy steel and stainless steel. In 85-5-5-5 fluidity improvement was as much as 125 per cent and in the low alloy steel it was up to 154 per cent.

Mold coatings (hexachloroethane and carbon black), properly applied, have no deleterious effects on x-ray quality, surface appearance or mechanical properties of aluminum castings. Mold coatings can significantly improve mechanical properties of aluminum castings by permitting substantially reduced pouring temperatures. For example, in an aluminum-4.5 per cent copper alloy test casting, coatings permitted lowering the pouring temperature 100 F. As a result, elongation was doubled (increased from 4 per cent to 8 per cent) with a simultaneous increase in tensile strength.

ACKNOWLEDGMENT

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FOUNDRY AIR POLLUTION CONTROL IN THE SAN FRANCISCO BAY AREA

by B. Linsky and G. Aase

ABSTRACT

A discussion on the basic need of an Air Pollution Control District, covering such items as localized effects and terrain of the District, the meteorological and climatic conditions that prevail in the area, pollutant measurements which have been made and a survey of total emissions is presented. An initial study of the problem was a survey of air pollution control regulations adopted in other areas, including discussions with eminent professional people in the air pollution field. There was an organization of concepts and principles, and these were talked about in many meetings with interested industry groups ending with the first draft of Regulation 2.

A condensed version of Regulation 2 is given, covering the five classes of source operations, general limitations and some of the features not found in other regulations, to tell why sampling methods were included as a part of the regulation and to give a review of sections of particular interest to foundry operators.

A literature review of the main source operations in foundry practice of foundry emissions is presented, giving a chemical and physical description of these emissions and, where possible, a rate or way to estimate the amount of emissions. Controls being installed to meet the emission limits are shown, including a breakdown of foundry source operations with a description of the control method of methods being used or installed. Some of the problems which have been encountered are included.

The control of organic vapors from core ovens and similar operations is part of future trends. An increased coverage of foundry floor operations, a discussion on expected technical advances in operating practices and control methods and devices is presented.

INTRODUCTION

Air pollution control regulations are not new in the industrial sections of the United States. While at first they were applied to such areas as townships or within city limits, we now see them applied to whole counties and in some instances a multi-county area. Entire states are beginning to be subject to certain laws relative to air pollution.

The Bay Area Air Pollution Control District is the first of the truly metropolitan regional agencies to be established in the air pollution control field. It has recently issued what may be referred to as a West coast type of air pollution control regulation, Regulation 2. This regulation has a decided effect upon metal melting operations within its six county jurisdiction, some of which will be shown in this paper.

B. LINSKY is Air Pollution Control Officer and G. AASE is Principal Engr., Bay Area Air Pollution Control District, San Francisco, Calif.

AIR POLLUTION REGULATION

On the whole there was little disagreement over the need for air pollution control regulations. However, many foundrymen were not convinced as to the need for the degree of control which was placed in the regulation. Similar legislative activity with the establishment of limits on the emission of air contaminants is under way in many new areas which are not now subject to this type of regulation.

Prior to the establishment of an air pollution control agency there has to be a need shown that either a potential problem exists or that a problem is present. This is often brought out in public hearings, usually backed with detailed technical information describing the local situation. There may be presented reports containing data from studies of meteorology, local terrain, air pollution measurements, visibility studies, etc. Evidence of damage to property or vegetation may be shown.

Evaluation of air pollution and its effects is specialized, and requires study so that intelligent analysis can be made of the data presented. Leaders and speakers for the foundry industry should have a good speaking knowledge of air pollution in order that their words are received with proper recognition.

INVERSION CONDITIONS

Meteorological studies had an important role in setting up the San Francisco Bay Area District and its program. Two factors became apparent, the first concerning the inversion conditions which are prevalent along most of the West coast of the United States, and second, the frequency and duration of periods with light variable winds. An inversion is a stable atmospheric situation which favors the buildup of air pollutants by allowing them to pass through the inversion layer into the upper atmosphere. When this upper level air flow is shut off only horizontal wind movement remains as a means by which air pollutants can be diluted and/or removed.

Inversions in the San Francisco Bay Area are most frequent during the summer and fall months. Average frequency over this period is 86 per cent with variations from 98 per cent in July to over 70 per cent in November. It is evident that a day without an inversion is unusual during this period.

Light variable winds are considered as those winds in the zero to three mph range with no definite direc-

tion. In the San Francisco Bay Area these stagnant or light variable winds are present 22 per cent of the time, ranging from 5 per cent during July to as high as 44 per cent of the time during November. The combination of inversion layers, low surface wind speeds and mountain ranges or long valleys can lead to a serious buildup of air contaminants (see map).

AIR CONTAMINANT MEASUREMENT

Direct measurement of some of the air contaminants or groups of contaminants are made routinely. These are associated with undesirable air pollution effects such as visibility reduction, eye irritation, odor, vegetation damage and other property damage. Among the general group most measured are the oxidants which include ozone and organic peroxides. Oxidant measurements are used as an index showing relative amounts of eye irritating compounds in the atmosphere. The available data show that the peak oxidant concentrations in the San Francisco Bay Area are about half those found in the Los Angeles Basin.

An important factor considered in establishing the Bay Area Air Pollution Control District was the expected population and industrial growth of the area. Experts are showing a doubling of the Bay Area population every 20 years, with the total industrial output doubling each 12 to 15 years. From these facts and projections it is apparent that any air pollution problems in existence at present would become increasingly serious as time goes on unless active program for control were initiated.

Some of the pertinent sections of the legislative act establishing the Bay Area Air Pollution Control District (B.A.A.P.C.D.) must be highlighted as background information that determines the form of any regulation that can be written. The law, approved in July, 1955, made no provision for a permit system in the district program. The use and issuing of permits has been a basic operating tool of air pollution control agencies for many years. District regulations have been written to be as effective as possible without the permit procedure.

The basic law sets up the legal procedures to be followed when handling violations of the regulations. The common practice of working along misdemeanor lines is not a part of the legislative act. The decision of the Hearing Board and then a Superior Court is required to curb a violation of the regulation. The legislative act also states that no order, rule or regulation of the district shall specify the design of equipment, type of construction or particular method to be used in reducing the release of air contaminants.

NEW REGULATION

The District staff, after consultation with the Advisory Council, was directed by the Board of Directors to write a regulation controlling the emission of particulate matter from industrial sources and combustion including incineration and also controlling pollutant gases related to combustion.

Historically, all but the world's first air pollution control regulation have been used by control agencies and their legislative bodies as bases upon which to build new regulations. This was also true to a degree in the development of regulations by the B.A.A.P.C.D. A study was made of regulations already in effect in various parts of the United States. This has had double importance from an engineering viewpoint as proof that certain standards can and are being met, and that design criteria are available.

In addition to the study of existing regulations, contacts were made with many highly respected persons, considered as experts in the field of air pollution, as to new ideas, new approaches, new concepts, new standards, etc., which might be used to produce a better regulation. Another step was an inventory and classification of emissions from all types of sources within the six county area.[1] This survey was used to determine the objectives of the District program; i.e., the degree of control and cleanup required to satisfy the demands of the general citizenry for a cleaner atmosphere.

Prior to the writing of the first draft of the regulation, meetings were held with industrial and other groups in the Bay Area to obtain additional suggestions, approaches and details, and to verify the surveys. Considerable time and deliberation was taken between the first preliminary draft and the adoption of the regulation. This entailed study by industry groups, public hearings and the final resolving of the regulation through combined efforts of the Advisory Council and the District staff.

FOUNDRY REGULATIONS

The regulation affecting metal melting and auxiliary operations is considered by some to be quite complex. Part of this can be attributed to demands for greater precision in technical interpretations and legal procedures. The regulation divides industrial and commercial operations into five classes. Operations within these classes are grouped to allow maximum coverage with a minimum number of controlling rules. The regulation places emission limits on these classes of operation; incineration, salvage, heat transfer, general combustion and general operations.

Incineration hardly needs defining because it denotes burning to reduce the bulk in the disposal of combustible waste material. Salvage operations are of some importance to foundry people, as in this category are placed such operations as the burning of insulation from copper wire or armatures. It also includes the recovery of lead or aluminum in those furnaces where a portion of the charge remains unmelted.

A heat transfer operation involves the combustion of a fuel for the principal purpose of utilizing the heat of combustion through the indirect transfer of such heat to a process material. Prime examples are the steam boiler or indirect fired ovens and driers. There is no direct contact between the products of combustion and the material being processed.

A general combustion operation consists of any operation where combustion is carried on which is not by definition an incineration, salvage or heat transfer operation. In general combustion operations, combustion gases are in direct contact with the material being processed. Examples of general combustion operations are a cupola operation, an electric arc

(Reproduced through courtesy of John H. Andrews & Co.)

Map of area under the jurisdiction of the San Francisco Bay Area Air Pollution Control District.

furnace, reverberatory furnace, cement kiln and most dryer operations.

General operations cover all operations not utilizing combustion. Examples are foundry shakeouts, sand handling and screening. Induction melting usually comes under this heading.

Opacity Limitations

All of the classes of operation are subject to the Ringelmann and Equivalent Opacity limitations. These place a 3 min limitation in any hour on emissions as dark or darker than Ringelmann No. 2, or of such opacity as to obscure an observer's view to a degree equal to Ringelmann No. 2. Additional reference will be made to this section of the regulation.

The regulation contains specific requirements concerning sulfur dioxide emissions from all classes. Normally sulfur dioxide is not a problem with foundry people, but those interested will find this new approach to a problem most interesting. Sulfide ore roasting and used automobile battery recovery operations are directly concerned with this problem.

General Combustion and Operation

The major percentage of operations carried on within the foundry will fall into the general combustion and general operations groups. The regulation places the same basic air pollution abatement requirements on both classes. Measured emissions from these two classes are not subject to a carbon dioxide or oxygen correction. This should be remembered when making comparisons with existing regulations in other communities, because it has long been a subject of controversy around the United States whether the same rules can or should be used to govern steam boilers and a cupola. Under the Bay Area regulation the cupola is general combustion, the steam boiler furnace is heat transfer.

Foundry operations, like others in the general combustion and general operations classes are required to meet all the provisions pertaining to these classes. One is that particulate matter in the exhaust gases cannot exceed 0.30 grains/standard dry cu ft. However, in nearly all instances other, more restrictive, rules will govern; opacity or the process weight rule. Opacity has already been explained, but a related rule in the regulation stipulates that opacity determinations cannot be made within a bonafide building. Basically, the process weight type of rule sets up the allowable emission rates for particulate matter as a small percentage of the amount (weight) of material being processed in a unit of time, usually per hour.

The process weight rule has an interesting origin.[2] It was based on many measurements made principally on metallurgical operations. Two additional factors were introduced; the size of the operation and the required degree of control. The collection efficiencies required were those that could be obtained with commercial equipment that was then within economic reach of industry. Large industrial units constitute a greater point source of atmospheric contamination, and can usually handle higher efficiency collection more economically than small units.

The process weight concept does not take into consideration any relationship between the volume of effluent gases and the weight of solids discharged at the stack. It simply and effectively limits the amount of solids discharged and makes it unnecessary to consider dilution in control standards.

The first process weight rule that is known of was adopted by the Los Angeles County Air Pollution Control District in March 1949. This means that for over ten years the designers and manufacturers of air pollution control equipment have been doing the required engineering and have been installing equipment which meets this rule. This more than ten years' experience is a strong deterrent against changing any of the figures in the rule.

About the only change that has been made is for those industries with a process weight rate over 60,000 lb/hr. In the San Francisco Bay Area regulation the emission limits have been increased over the Los Angeles allowance for processes beyond the 30 ton an hour size with the numbers fitted into a mathematical formula. Table 1 shows the allowable rates of emission based on the process weight rate.

Other Parts of Regulation

A discussion of the regulation is not complete without describing some sections written into the regulation at the specific request of the Advisory Council. A five year "Grandfather Clause" was placed in the regulation, giving an additional 25 per cent allowance on the process weight rule. This pertains to processes that were in operation at the date of adoption, and expires on May 4, 1965 with certain filing requirements by May 4, 1963.

A minimum "grain loading floor" has been placed in conjunction with the process weight rule. The process weight rule thus modified does not require the reduction of particulate matter in the source gas below the limits set in Table 2.

A minimum grain loading floor was also placed in the regulation in conjunction with the Ringelmann and Equivalent Opacity rule. An operation shall be considered as meeting the visible limitations if the emission does not contain more than n grains of particulate matter/standard cu ft, where n equals 0.12 divided by L, and L is the significant dimension of the emission point in feet. L is equal to the square root of the area of the emission point.

The use of these two minimum grain loading rules are subject to several qualifications which can best be interpreted by actual study of the regulation.

Sampling Procedure

Among the definitions is one describing particulate matter. This is given greater significance by including as a part of the regulation the sampling procedure which is being used. In actuality this arrangement gives greater precision as to what can be measured, and what constitutes particulate material. Every attempt is made to determine particulate matter as it exists at the point of sampling with a special provision for gases over 500 F (260 C).

Another feature of the regulation is the initial allowance of time to bring an existing operation into

compliance. The Air Pollution Control Officer was authorized, until Oct. 1, 1960, to receive detailed program schedules and grant time beyond the effective date of Jan. 1, 1961 for necessary engineering, procurement, fabrication, installation and adjustment when there was and continued to be a showing of satisfactory progress toward compliance with the regulation. Most of the foundry compliance schedules were straightforward engineering task schedules. The problems of foundries that failed to make their moves are being dealt with now to avoid giving them competitive advantages over their complying neighbors.

Core ovens are a source of fumes and odors. These units are now subject to the visible emission limits which usually, but not always, result in controlling the odorous gases. A future regulation is planned to provide a general coverage of hydrocarbon emissions from general combustion and general operations. Additional formal limitations will then be placed on core oven operations.

During the time when meetings were being held with various industry people including foundrymen, it became apparent that there was a general lack of knowledge among these groups as to what was being emitted from either their individual processes or their plants. This became important when they were evaluating the economic effect of the proposals on degree of control, for the degree of control decides the final cost of air pollution abatement installations.

Fine Particle Control

The regulation of the B.A.A.P.C.D. has been called a "fine particle control" regulation. This means that a knowledge of the physical as well as the chemical properties of the emission must be known. Particle size determinations are expensive and time consuming and are often given the role of a research project. This information is not always readily available. Some of it is in the files of the designers and manufacturers of air pollution control equipment. A few large operating corporations with specific engineering divisions that handle dust and fume problems also have such data.

The largest concentrated sampling program of emissions from industrial sources of air pollution has been conducted by the Los Angeles County Air Pollution Control District. Some of their findings have been released as technical progress reports and reports of investigations. Many of the original studies[3] included particle size distribution as well as emission rates. They have found that an average cupola will discharge about 17 lb of particulate matter for every ton of metal processed, and that about 14 per cent by weight of this particulate matter will be below 10 micron in size with 7.5 per cent by weight below 5 micron diameter.

Studies on electric arc furnaces for steel production show an average of 8 lb of particulate matter per ton of metal processed with practically all under 3 microns in diameter. Zinc oxide fume is extremely fine, most of it being submicron in size. Table 3 gives a review of emission rates from various metal melting operations in Los Angeles County.

The American Foundrymen's Society has issued two publications that adequately list the operations in the foundry that are a source of air contaminants. The "Foundry's Attack on Air Pollution" published in the Sept. 1956 issue of MODERN CASTINGS, and the FOUNDRY AIR POLLUTION CONTROL MANUAL, are both recommended reading for anyone as an aid to evaluation of air pollution control legislation or the control of a specific foundry air pollution problem.

TABLE 1* — ALLOWABLE RATE OF EMISSION BASED ON PROCESS WEIGHT RATE[a, b]

Process Weight Rate		Rate of Emission,	Process Weight Rate		Rate of Emission,
Lb/Hr	Tons/Hr	lb/hr	Lb/Hr	Tons/Hr	lb/hr
100	0.05	0.551	16,000	8.0	16.5
200	0.10	0.877	18,000	9.0	17.9
400	0.20	1.40	20,000	10.0	19.2
600	0.30	1.83	30,000	15.0	25.2
800	0.40	2.22	40,000	20.0	30.5
1,000	0.50	2.58	50,000	25.0	35.4
1,500	0.75	3.38	60,000	30.0	40.0
2,000	1.00	4.10	70,000	35.0	41.3
2,500	1.25	4.76	80,000	40.0	42.5
3,000	1.50	5.38	90,000	45.0	43.6
3,500	1.75	5.96	100,000	50.0	44.6
4,000	2.00	6.52	120,000	60.0	46.3
5,000	2.50	7.58	140,000	70.0	47.8
6,000	3.00	8.56	160,000	80.0	49.0
7,000	3.50	9.49	200,000	100.0	51.2
8,000	4.00	10.4	1,000,000	500.0	69.0
9,000	4.50	11.2	2,000,000	1000.0	77.6
10,000	5.00	12.0	6,000,000	3000.0	92.7
12,000	6.00	13.6			

a. Sections of major importance with reference to this table are ss 2024, 2027, 3213, 3214 and 6112.2.

b. Interpolation of the data in table for process weight rates up to 60,000 lb/hr shall be accomplished by use of the equation $E = 4.10\ P^{0.67}$, and interpolation and extrapolation of the data for process weight rates in excess of 60,000 lb/hr shall be accomplished by use of the equation;

$E = 53.0\ P^{0.11} - 40$, where E = rate of emission in lb/hr and P = process weight rate in tons/hr.

* Bay Area Air Pollution Control District, Regulation 2, May 4, 1960.

TABLE 2* — MINIMUM CONCENTRATION TO BE REQUIRED[a, b]

Source Gas Volume, SCFM	Concentration GR/SCF	Source Gas Volume, SCFM	Concentration GR/SCF
7,000 or less	0.100	140,000	0.038
8,000	0.096	160,000	0.036
9,000	0.092	180,000	0.035
10,000	0.089	200,000	0.034
20,000	0.071	300,000	0.030
30,000	0.062	400,000	0.027
40,000	0.057	500,000	0.025
50,000	0.053	600,000	0.024
60,000	0.050	800,000	0.021
80,000	0.045	1,000,000	0.020
100,000	0.042	or more	
120,000	0.040		

a. Sections of major importance with reference to this table are: ss 2024, 2030, 6112.3 and 6112.4.

b. Interpolation of the data in this table shall be based on linear interpolation between adjacent values.

* Bay Area Air Pollution Control District, Regulation 2, May 4, 1960.

TABLE 3 — EMISSIONS OF AEROSOLS FROM METALLURGICAL OPERATIONS IN LOS ANGELES COUNTY*

Source	Emissions in lb/ton of Metal Processed	
	Uncontrolled	Controlled
Open Hearth Steel Furnaces (58 ton capacity[a]	17.8	0.36
Gray Iron Melting Cupolas (Avg.)	17.1	0.26
Less than 48 in. I.D.	12.9	—
48-60 in. I.D.	19.5	—
Greater than 60 in. I.D.	18.9	—
Electric Steel Melting Furnaces (Avg.)	8.6	0.17
Less than 5 ton capacity	10.6	—
5-20 ton capacity	5.7	—
50-75 ton capacity	9.6	—
Melting of Red Brass		
Crucible or Pot Furnaces	3.3	—
Rotary Furnaces	21.3	10.1[b]
Reverberatory Furnaces	16.8	—
Electric Furnaces	3	—
Melting of Yellow Brass		
Crucible Furnaces	14	5.1[b]
Rotary Furnaces	—	22.8[b]
Reverberatory Furnaces	—	5.7[c]
Electric Induction Type Furnaces	0.7	—
Melting of Bronze		
Crucible Furnaces	3.8	—
Rotary Furnaces	30.6	4.7
Melting of Aluminum		
Crucible Furnaces	1.9	—
Reverberatory Furnaces	5.2	2.1

a. Principally scrap remelt.
b. Using slag cover as the only control method.
c. With baghouse control.
* Air Pollution Control District County of Los Angeles, Control of Stationary Sources, Technical Progress Report, *vol. 1*, (1960) p. 31, Los Angeles, Calif.

FOUNDRY INSTALLATIONS

Some of the foundries in the San Francisco Bay Area have not completed their engineering studies, but apparently most of them are going to use conventional, highly effective methods in bringing their operations into compliance with the regulation. The major cupola operations are installing baghouses with either stack igniters or afterburners. As far as is known, all will be using glass cloth as the filter media. Some plants will be installing heat reclaiming equipment for heating tuyere air, which will allow some utilization for production heat of the natural gas required to complete the combustion of the cupola gases for air pollution control. This exchange of heat can also help in lowering the temperature of the gases going to the collectors.

Some new ideas in gas cooling have been proposed but so far vertical towers with water sprays have been selected. A few gray iron foundries are looking to induction melting or gas fired reverberatory melting for reducing their emissions, while at the same time improving their production factors. At least two foundries have made commitments to go to gas melting.

In many instances the installing of control equipment brings added problems to the foundry operator. Space may be a problem where areas for baghouses, cooling towers, ducting and fans are not readily available and some rearrangement of facilities may be required. Electrical distribution can also be troublesome. The addition of electrical horsepower in a foundry through the past years has sometimes reached the point where the existing electrical system is operating at maximum load. The additional kw needed for a control system may require a new substation, switchgear and other auxiliary equipment.

One San Francisco Bay Area foundry encountered a situation that required an entirely new cupola charging system to be designed and installed. This, in itself, has turned out to be a major engineering undertaking.

NONCONTROLLED SOURCES

The present regulations of the B.A.A.P.C.D. leave some types of air pollution from some types of industrial sources yet to be controlled. These concern organic vapors, odorous gases and particulates and some inorganic gases. A special study will be made of these sources including methods of control to determine equitable limits on invisible as well as visible emissions. Core oven operations will be a part of this study.

Increased coverage of foundry floor operations can be expected at some future time. Modernization and mechanization of mold handling and pouring will be a part of this study program. Any future increase in air pollution control in the foundry should be more than balanced by improvements in methods and equipment used to collect dust and fumes. Great advances have been made in the last decade and this trend can be expected to continue along with the other technical developments.

More efficient gas cooling and higher operating temperatures for control equipment will reduce the size of air pollution abatement equipment. The allowable temperatures for baghouse operation have gone from 275 F to 550 F (135 to 288 C), with test work on new filter material at 750 F (399 C) being reported. Great developments are expected along these lines, as new synthetic fibers are discovered.

Changes in melting practice, better scrap preparation and, in some cases, a decrease in scrap use, will contribute new benefits to the metal melting industry including relief from air pollution problems. Alternate alloys are being developed to replace some of the problem metals now being cast.

Comparable progress is shown for core room practice and sand molding as new materials are introduced and new techniques developed. Some have caused a major reduction in the amounts of air contaminants being emitted from these equally important foundry operations.

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GRAPHITE FORMATION DURING SOLIDIFICATION OF CAST IRON

Flake, spheroidal, lacy, film and compact graphite

by C. R. Loper, Jr. and R. W. Heine

ABSTRACT

The principles of graphite formation during solidification of cast irons containing flake, spheroidal, lacy, film-type and compact graphite of the type occurring in as-cast malleable iron are described. Cooling curves and quenching of small samples from important temperatures during cooling were used to show the sequence of events in the development of the various types of graphite. With respect to flake graphite, agreement with the work of previous investigators was reached. Graphite flakes were found to grow in contact with the melt and as part of the two phase austenite-graphite eutectic.

Compact graphite of the type present in a currently produced as-cast malleable iron was found to nucleate and grow after solidification and at temperatures at and below the A_{cm} solubility curve. Film-type graphite is formed in the same way. Spheroidal graphite was observed to nucleate at temperature above the eutectic temperature range in both hypo and hypereutectic irons. Growth occurred only upon reaching the upper eutectic temperature. Growth of spheroids continues down to temperatures well below the normal lower eutectic temperature. Growth of spheroids occurs while they are encased in austenite, i.e., they are not in contact with the liquid.

The number of spheroids was found to increase during cooling only to the eutectic start temperature, not in the eutectic range. Substantial increase in the eutectic solidification temperature range was demonstrated for ductile irons. The principles of graphite formation set forth describe the conditions under which the various types of graphite must form and explain why mixed types are found in some compositions. The effect of magnesium, cerium and other elements on the graphite formation process is described.

INTRODUCTION

The solidification and graphitization of cast irons has attracted many investigators over the past years, but is still not well understood. The subject is complex, and such problems as the metastability of iron carbide, the many types of graphite which develop, inherent variables of melting and casting and the effect of small amounts of additional elements other than iron, carbon and silicon must be recognized in such a study. Because of the complexity of the problem and the variety of the forms of graphite which occur, most investigators have limited their study to narrow ranges of chemical composition, and to the investigation of only one type of graphite as being distinct from the others.

As a result, the broader viewpoint of the solidification and graphitization process over wide variations in chemical analysis and graphite form has been overlooked. The purpose here is to consider this broader viewpoint, and to show that the forms of graphite are in the end all related but differ in the mechanism of precipitation from the melt or solid.

During solidification and cooling of the iron, these forms of graphite have been observed to occur:

1. Eutectic flake graphite. The graphite present in most gray irons typifies this graphite and may include types A, B, D and E according to the current AFS classification.
2. Kish or proeutectic flake graphite in hypereutectic gray or pig irons.
3. Spheroidal graphite. The true spheroids found in ductile iron typify this form.
4. Compact graphite. This form is found in certain types of as-cast malleable irons (and graphitic steels).[10,35,48]
5. Film graphite. This type is not intentionally produced in any commercial cast iron, but is sometimes observed.[10,48]
6. Lacy graphite.

Some forms other than those listed may seem to occur, but according to present knowledge these appear to be variations of the basic graphite forms listed. The graphite forms develop during cooling of the iron from the casting temperature. This study will not be concerned with graphitization which occurs as a result of some heat treatment of solidi-

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fied and cooled cast iron such as annealing or malleablizing.

REVIEW OF PREVIOUS WORK

Extensive reviews of the literature on the solidification and graphitization of cast irons have been compiled by Parthasarathi, Srikantiah, and Nijhawau,[17] Morrogh and Williams[15] and Gries and Maushake.[18] In this literature review, the authors present what seems to be the consensus of the various investigators as to the solidification mechanism of cast irons, and, in particular, the method of graphite formation.

The literature is fairly well agreed that eutectic flake graphite is formed while in direct contact with the liquid iron. A hypoeutectic gray cast iron would solidify in the pattern:

1. Austenite dendrites in the liquid, formed above the eutectic arrest.
2. At the eutectic arrest, the eutectic of austenite and graphite solidifies on a spheroidal crystallization front (cellular growth). Ends of the flake graphite are in contact with the liquid.
3. On completion of the eutectic solidification, the austenite of the eutectic become continuous.

A hypereutectic gray cast iron would solidify in a related fashion:

1. Above the eutectic arrest, primary crystals of kish graphite form in the liquid.
2. The eutectic solidification is similar to that of a hypoeutectic gray cast iron, except that the cells are nucleated as kish graphite.
3. On completion of solidification of the eutectic, the structure consists of long flakes of kish graphite and eutectic flake graphite similar to that obtained in the hypoeutectic gray cast iron.

The literature is divided, however, on the solidification mechanism involved in a cast iron of lower carbon and silicon content or a cast iron cooled at a faster rate. Graphite in these alloys would be present as type E or type D[19] undercooled graphite. Morrogh,[15] Eash[24] and others state that undercooled graphite forms on decomposition of iron carbide solidified in the eutectic. Hultgren, Lindbolm, and Rudberg[29] and others have shown that type D graphite may form as a cellular structure with the graphite flakes in direct contact with the liquid.

The solidification of cast irons containing flake or undercooled graphite involves many anomolies which require explanation, correlation or proof. Forty-one of the more important anomolies have been listed by Morrogh and Williams,[15] and will not be presented here.

There are almost as many theories in the literature concerning the solidification of ductile irons as there are investigators. Gries and Maushake[18] group these theories according to three problems:

1. The nuclei from which the graphite spheroids originate. Twelve different theories are presented as to the structure of the nuclei. The majority of the authors believe this nucleus to be some type of carbide.
2. The crystal structure of the spheroids. The majority of the investigators believe spheroids are crystal aggregates, the base planes of which are normal to the radius.
3. The manner of crystallization of the spheroids and the matrix and the relationship to them. Eighteen theories on the mode of crystallization of spheroids and matrix are advanced, the majority of which state that supercooling is observed. The theories are equally divided as to whether it is necessary for the graphite nodule to be surrounded by austenite or whether the graphite nodule develops while in intimate contact with the liquid.

In general, then, the mode of solidification of ductile iron is not well established, at least as far as the formation of graphite nodules is concerned. There is no mention in the literature of the solidification mechanism of cast irons containing compact or film or lacy type graphite.

EXPERIMENTAL PROCEDURE

The solidification and graphitization process was studied using the technique of interrupted slow cooling of small samples. Several iron-carbon-silicon alloys were selected for study according to the type of graphite expected in their microstructures. These alloys were:

1. Alloy A — 0.98% C, 3.52% Si. A cast iron which contains compact graphite.
2. Alloy CS — 1.55% C, 2.33% Si. An as-cast malleable iron containing compact graphite.[10,35]
3. Alloy F — 3.12% C, 1.70% Si. A hypoeutectic flake graphite cast iron.
4. Alloy GR — 3.90% C, 2.16% Si. A hypereutectic flake graphite cast iron.
5. Alloy GR′ — 4.00% C, 2.30% Si. A commercially produced ductile cast iron, hypereutectic in composition.
6. Alloy GSW — 3.54% C, 2.14% Si. A commercially produced ductile cast iron, hypoeutectic in composition.

Additional details of chemical composition of these alloys are given in Table 1. Samples of these alloys to be used in the interrupted cooling experiments were obtained by drawing a sample of the molten iron into a ¼-in. inside diameter glass tube and immediately quenching it into water. Samples were then broken off into sections about 1⅜-in. long.

The interrupted slow cooling of samples was carried out in the furnace shown in Fig. 1. It consists of a cylindrical furnace heated by means of a hollow cylindrical globar heating element, 2 in. inside diameter x 16 in. long. The electrical connections on either end of the vertically mounted heating element were water cooled and were surrounded by 6 in. of insulating material. The power input to the furnace could be varied so that the heating and cooling rate of the furnace could be controlled.

Samples were melted down in fused silica tubes, ⅝-in. inside diameter and fused closed on one end.

TABLE 1 — CHEMICAL COMPOSITION

Alloy	Analysis, % C	Si	S	P	Mn	Graphite Type	Iron Type
A	0.98	3.52	0.06[1]	—	0.60[1]	Compact	As-cast Malleable
CS[2]	1.55	2.33	0.099-0.127	0.05[1]	0.58-0.63	Compact	As-cast Malleable
F	3.12	1.70	0.06[1]	—	0.60[1]	Flake	Gray Iron
GR	3.90	2.16	0.012	0.016[1]	—	Flake	Gray Iron
GR[3]	4.00	2.30	0.008	0.016	—	Spheroidal	Ductile Iron
GSW[4]	3.54	2.14	0.011	0.016[1]	—	Spheroidal plus Flake	Ductile Iron

1. Estimated analysis.
2. 0.01% B also present.
3. About 0.050% Mg also present.
4. 0.051% Mg present before re-melting; 0.028-0.031% Mg present in re-solidified samples.

These fused silica tubes containing the samples were shielded from the direct radiation of the heating element by means of a one in. inside diameter zircon combustion tube. A 2¼-in. long zone over which the temperature gradient was ± 3 F was produced by this arrangement.

Several platinum 10 per cent rhodium-platinum thermocouples were used in the assembly and are shown in Fig. 1. One, connected to the furnace controller, was placed between the combustion tube and the heating element. The second couple was placed inside the zircon combustion tube in such a manner that it would be within ⅛-in. of the sample in the fused silica tube during the experimental runs. This couple was connected to a recorder having a 1000 to 3000 F scale and a chart speed of 4.8 in./hr.

Cooling Curves

Cooling curves for thermal analysis of the alloys investigated were obtained by placing another platinum 10 per cent rhodium-platinum thermocouple directly into the melted sample. A fused silica tip was fixed onto the end of a high temperature refractory insulator to protect the couple from the molten metal. The cooling curve obtained from this couple immersed in the molten metal was compared with the cooling curve of the couple adjacent to the sample. Figure 2 shows the results obtained with these two couples for one of the cast irons studied (3.12% C, 1.70% Si). After having obtained these cooling curves, the couple adjacent to the fused silica tube was then used to determine the temperature of the samples in subsequent experimental runs.

The samples to be studied were placed in the fused silica tubes, held in the furnace at temperature (generally 2700-2750 F) for 10 min. and then cooled in the furnace at 10-15 F/min. After the samples had furnaced cooled to various specific temperatures, they were quenched into cold water. The samples were then examined metallographically. Determination of the number of graphite spheroids per sq mm or per cu mm were made by the method described in a reference.[5]

The importance of cooling rate of the specimen should be recognized. Although the specimen is small,

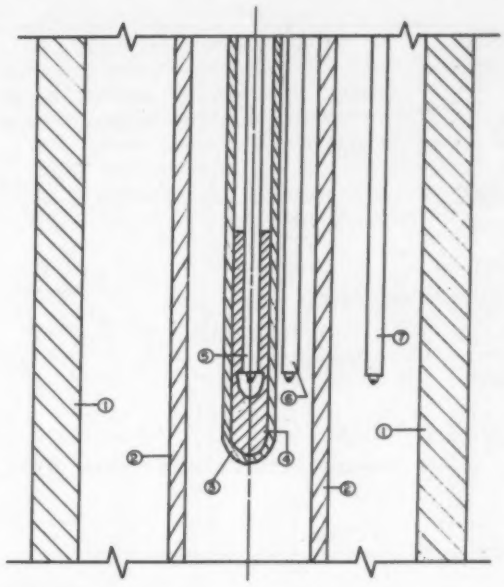

Fig. 1 — Schematic diagram showing globar tube furnace, tube holding molten sample and arrangement of three thermocouples for measuring and controlling temperature of the sample. (1) 2 in. I.D. globar heating element. (2) One in. I.D. zircon combustion tube. (3) 5/16-in. fused silica tube sealed at one end. (4) Molten cast iron sample approximately 8 grams in weight. (5,6,7) Thermocouples.

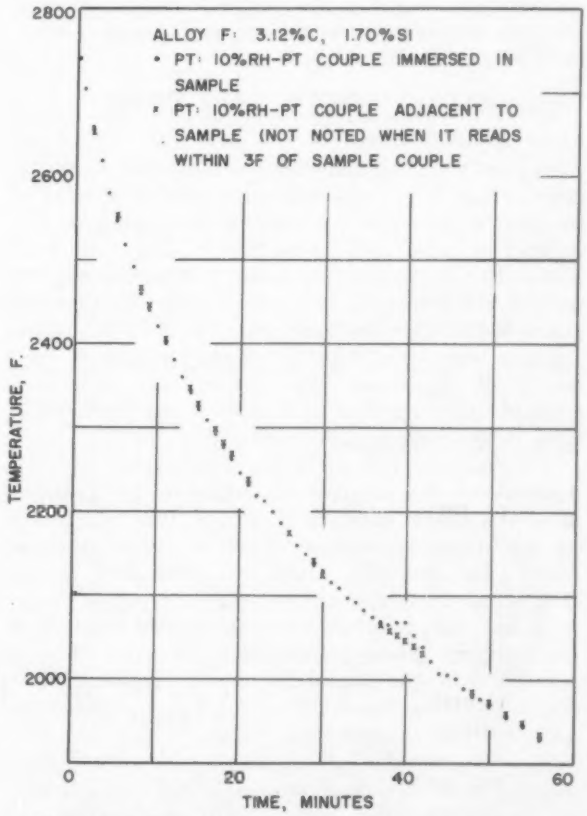

Fig. 2 — Comparison of cooling curve of molten sample with cooling curve of thermocouple immediately outside tube holding sample, TC 5 vs. TC 6 in Fig. 1.

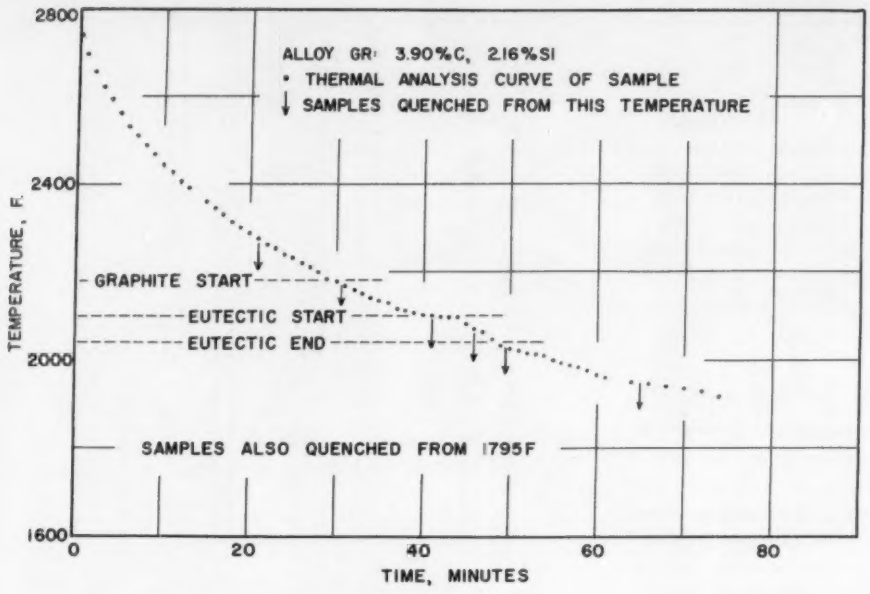

Fig. 3 — Cooling curve of alloy GR.

approximately 8 grams, it was cooled from the 2700-2750 F range to just below 2000 F in about 40 to 50 min for most samples, and from 2250-2300 F in about 13 min in other cases. This is equivalent to the cooling time in an infinite 4 in. square bar or 2 in. plate section of cast iron in molding sand.

In addition to the solidification studies performed in the laboratory, thermal analysis and quenching experiments were performed on ductile iron castings in a commercial foundry.

HYPEREUTECTIC CAST IRONS

Flake Graphite Irons

The solidification and graphite formation in hypereutectic cast irons was studied in an alloy of 3.90 per cent C and 2.16 per cent Si. This alloy is designated as alloy GR. Samples of alloy GR were heated to 2700-2750 F and held at that temperature for 10 min before cooling was started. The cooling curve of this alloy, and the temperatures from which samples were quenched, are shown in Fig. 3. Also shown in Fig. 3 are the temperatures designated graphite start, eutectic start and eutectic end which were determined metallographically.

The results of this study are in agreement with the majority of the previous investigators. No evidence of a proeutectic constituent of any type was noted in the quenched samples until a temperature of 2190 F was attained. Quenched from 2190 F, the sample consisted entirely of quenched liquid except for a few short graphite flakes distributed throughout the structure. These graphite flakes were in intimate contact with the liquid at the temperature from which they were quenched, and no shell of austenite was observed around these flakes.

Austenite was not present in the structure of these samples until a temperature of 2100 F was reached. At this temperature, eutectic cells of austenite and flake graphite were nucleated (by the proeutectic graphite flakes) and grew with decreasing temperature. These eutectic cells were observed to grow radially and with the ends of the graphite flakes in contact with the liquid metal. Growth of both the kish graphite (proeutectic graphite) and the eutectic flake graphite took place with the graphite flakes in direct contact with the liquid metal. The growth of the eutectic in this manner is the same as that described by Boyles.[23]

Solidification of the austenite-flake graphite eutectic took place over a temperature range of about 60 F. The eutectic freezing range was established metallographically at 2100-2040 F, and is in agreement with the thermal analysis data presented in Fig. 3. When eutectic cells nucleate at 2100 F and grow down to 2040 F at the 2.16 per cent Si level, random type A graphite flakes are expected and were observed. Since the microstructure of kish and eutectic cell growth during solidification have been well illustrated with photomicrographs,[15,23,24,49,50] these microstructures will not be shown again here.

In summary, hypereutectic gray cast irons, as characterized by alloy GR at 3.90 per cent C and 2.16 per cent Si solidify in the manner:

1. Formation of flakes of proeutectic graphite (kish) in the liquid melt at about 2190 F.
2. Growth of kish with decreasing temperature and subsequent possible flotation of this graphite due to the difference in specific gravity between the graphite and the liquid metal.
3. Nucleation of the cellular eutectic by the kish graphite at about 2100 F and growth of the eutectic cells and the kish graphite between 2100 and 2040 F. At 2040 F, solidification of alloy GR was completed.

Spheroidal Graphite Irons

The formation of graphite as spheroids in cast irons was studied using alloy GR′ (4.00% C, 2.30% Si). This alloy is a magnesium-treated, commercially-produced ductile cast iron of essentially the same analysis

as alloy GR, the hypereutectic gray cast iron. In order to prevent the loss of magnesium which occurred while holding the sample at 2700-2750 F for 10 min, it was necessary to modify the normal procedure followed. Without modifying the procedure, a flake graphite structure, like that of alloy GR, was obtained.

In addition to the effect of exposure time at 2700 F, loss of magnesium also occurred in those samples subjected to elevated temperatures of long periods of time while they were slow cooled. On the other hand, it was found that heating to temperatures lower than 2700 F for short times (4 min) was insufficient to dissolve the graphite spheroids in the structure. Although the sample was completely free of graphite initially, graphite spheroids developed during heating. This effect has been shown in Fig. 4, where it may be noted that the number of spheroids in the structure decreased as the temperature at which the sample was held for 4 min was increased. A temperature higher than 2600 F was necessary to dissolve all of the spheroids in 4 min.

In order to study the nucleation of graphite spheroids in this alloy, it was necessary to select combinations of temperatures and exposure times which would be sufficient to dissolve all graphite spheroids present in the sample, and at the same time retain an adequate amount of magnesium to insure spheroidal graphite formation during subsequent cooling. The number of spheroids retained in the melt after different temperature time cycles is given in Table 2. Table 2 also demonstrates the well-known fact that time is required to dissolve graphite when cast iron is heated into the molten state, and that this solution time is temperature dependent.

Using this necessary modification of the procedure already set forth, it was found that small, round graphite nuclei dissolve in 4 min at 2700 F and then reappear on cooling to about 2500 to 2450 F. These nuclei are present in all samples of alloy GR′ quenched from lower temperatures. Figures 5 and 6 show examples of this graphite particle in the unetched and etched condition. These graphite nuclei have been observed only in cast irons which finally solidify with graphite spheroids, as in ductile iron. It is also noteworthy that the carbides in which these nuclei are found are coarser than other carbides in the structure, and are also coarser than the carbides present in alloy GR′, the hypereutectic gray cast iron of approximately the same analysis.

Graphite Spheroid Formation

At lower temperatures these graphite nuclei develop into graphite spheroids, as shown in Figs. 7 and 8, for samples quenched from 2200 F and Fig. 9 for a sample quenched from 2150 F. The spheroids present in these samples are not in direct contact with the liquid at the quenching temperature, but are instead separated from the liquid by a thin shell of austenite. Evidence of this austenite shell is shown in Fig. 8, and is best seen in Fig. 9. The quenched liquid appears as rods of carbide with areas of prior austenite. These photomicrographs show that the spheroids begin to grow rapidly between 2250 and

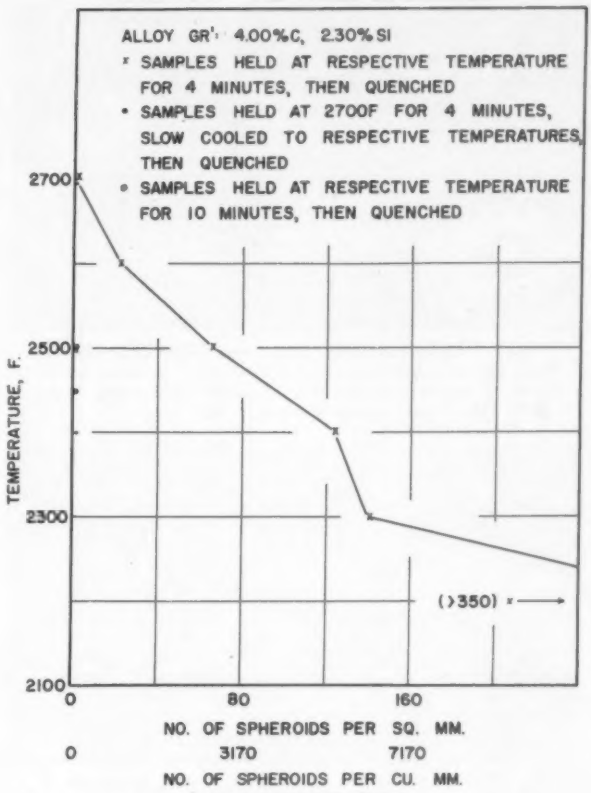

Fig. 4 — Effect of molding melt 4 min at temperature on number of undissolved spheroids in melt. Also showing that holding 10 min at temperature is long enough to completely dissolve spheroids above 2400 F.

2200 F and even more so between 2200 F and 2150 F and 2150 F, Fig. 8 vs. Fig. 9.

The number of spheroids formed increases with decreasing temperature for alloy GR′ until the

TABLE 2 — EFFECT OF TEMPERATURE AND TIME FOR DISSOLVING GRAPHITE IN A 4.00 PER CENT C, 2.30 PER CENT Si, MAGNESIUM-TREATED DUCTILE CAST IRON

Temperatures at which samples were held, F	Time at Temperature, min	Temperature to which samples were slow cooled, F	No. of Retained Graphite, Spheroids/mm²
2700	4	—	0
2700	4	2500	0
2700	4	2400	0
2500	10	—	0
2450	10	—	0
2700	4	—	0
2600	4	—	22
2500	4	—	65
2400	4	—	124
2300	4	—	140
2200	4	—	350
2250	10	2250	340
2250	10	2200	350
2250	10	2150	420
2250	10	2100	650
2250	10	2070	680
2250	10	2050	550
2250	10	2025	550
2250	10	1975	470

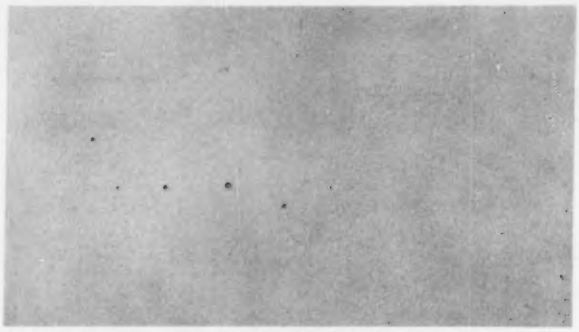

Fig. 5 — Hypereutectic ductile iron (4.00 per cent C, 2.30 per cent Si) quenched from 2250 F, showing presence of graphite nuclei. These nuclei are present from 2450-2500 F and down. Unetched. 1000×.

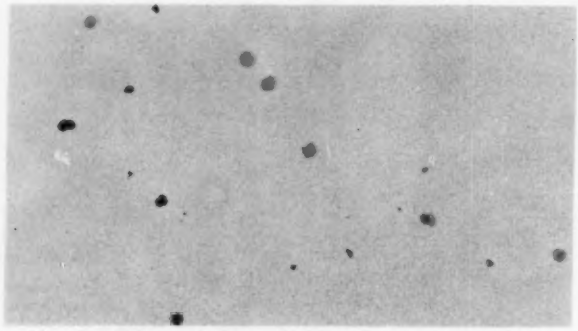

Fig. 7 — Same sample as in Figs. 5 and 6, except it was quenched from 2200 F. Growth of some of the spheroids has already begun over the temperature range of 2250 F down to 2200 F. Small nuclei are still present. Unetched. 250 ×.

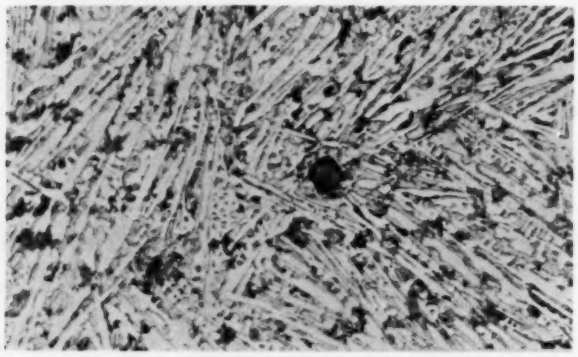

Fig. 8 — Same sample as in Fig. 7, showing austenitic shell which existed around spheroid which becomes martensite on quenching. 2 per cent nital etch. 250 ×.

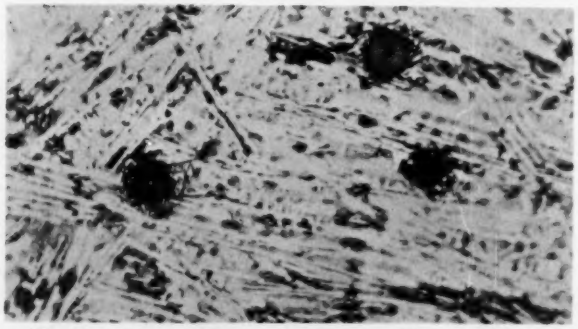

Fig. 9 — Same sample as shown in Figs. 5-8, but quenched from 2150 F. Note well developed spheroids and shell of austenite (quenched to martensite) encasing them. 5 per cent nital etch. 750 ×.

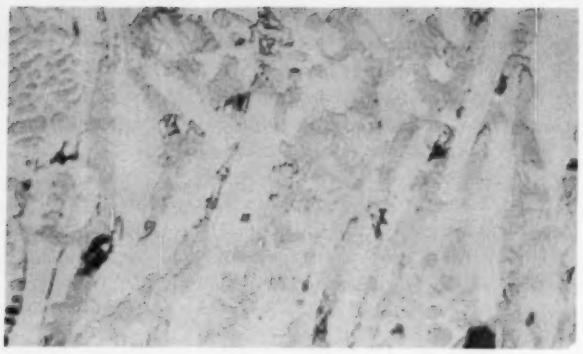

Fig. 6 — Same sample as in Fig. 5, showing location of graphite nuclei in coarse carbides of quenched liquid. 2 per cent nital etch. 1000 ×.

eutectic start temperature is reached at 2100 F. Over this temperature range, however, there is only a small increase in the size of the spheroids formed. This effect of temperature on the number of spheroids formed is shown in Fig. 10. The number of spheroids formed does not increase, and in fact decreases slightly, after the start of eutectic solidfication. After complete solidification of the alloy, the number of spheroids is essentially constant down to room temperature. The number of spheroids, illustrated in Fig. 10, should not be regarded as generally applicable to all ductile iron casting, because of the small sample size used. Rather Fig. 10 illustrates the principle of nucleation for this type of solidification.

All of the graphite spheroids formed were separated from the liquid metal by a thin shell of austenite. The thickness of this austenite shell was observed to be constant until the eutectic starts to solidify. In the temperature range of eutectic solidification some graphite spheroids rapidly grow to larger sizes, and at the same time the austenite shell surrounding them increases in thickness. Other spheroids present in the liquid do not take an active part in eutectic solidification and appear to remain dormant. Some of the smaller spheroids are re-dissolved in the liquid as the temperature decreases through the eutectic range.

The foregoing observations are illustrated by the temperature-spheroid number curve, presented in Fig. 10. The structure of a sample of alloy GR′ quenched from 2025 F, a temperature in the eutectic freezing range, is presented in Fig. 11. This photomicrograph shows both the large spheroids which have already taken part in the eutectic solidification and the dormant spheroids located in the quenched liquid. Subsequently most of the dormant spheroids will participate in the solidification of the remaining eutectic and increase in size as temperature decreases further. This process of eutectic solidification continues until all of the liquid is solidified (1985 F).

Thermal Analysis

The temperatures from which samples of alloy GR′ was quenched, and the thermal analysis cooling curve for this alloy, are shown in Fig. 12. Included in this graph are the metallographically determined eutectic start and end temperatures which are in

agreement with the thermal analysis data. A considerable difference is evident in the shape of the cooling curve for the hypereutectic flake graphite iron (Fig. 3) and the spheroidal graphite iron (Fig. 12). Most notable is the extended temperature range of solidification of the ductile iron. This difference has been noted by other investigators, and is to be expected because of the difference in the mode of formation of the graphite in the two cast irons.

The austenite flake graphite eutectic of the hypereutectic gray cast iron (alloy GR′) forms by the growth of eutectic cells of γ + graphite which are nucleated at various points throughout the specimen. These cells grow quite rapidly at first, causing the evolution of heat which prevents the temperature of the sample from falling. In this way the majority of the cellular flake graphite eutectic solidifies at almost constant temperature. The small amount of the eutectic remaining solidifies over the remainder of the eutectic range (60 F).

On the other hand, alloy GR′, the hypereutectic ductile cast iron, enters the eutectic solidification range containing graphite spheroids which are already surrounded by a thin film of austenite. Solidification of the eutectic then takes place by the precipitation of austenite onto the austenite shell surrounding the graphite spheroid, and the diffusion of carbon through the austenite shell to the graphite spheroid. In order for the spheroid to increase in size, iron must diffuse out so that carbon atoms may precipitate on the graphite spheroid.

As the thickness of the austenite shell increases, it becomes increasingly more difficult for sufficient diffusion to occur for growth to proceed. A decrease in temperature is then required to effect an increase in the driving force for the precipitation of graphite. Also, dormant spheroids with thinner shells will begin to grow as temperature decreases. Thus, the eutectic must solidify over a correspondingly greater temperature range (115 F for the ductile cast iron eutectic compared to 60 F for the gray cast iron eutectic).

It is convenient at this time to point out that

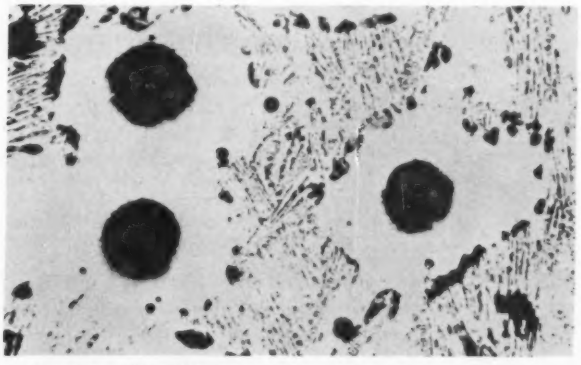

Fig. 11 — Sample of same iron, as shown in Figs. 5-10, except it was quenched from 2025 F. This temperature is in the eutectic solidification range, and the sample shows large spheroids encased in thick shells of austenite growing as part of the eutectic. Also evident are dormant, small spheroids in the quenched liquid. These will grow at temperature decreases. 2 per cent nital etch. 250 ×.

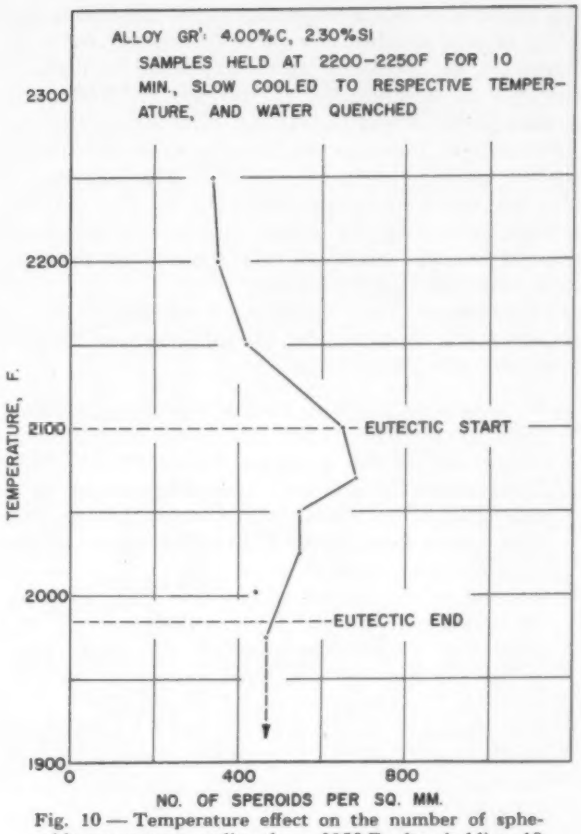

Fig. 10 — Temperature effect on the number of spheroids present on cooling from 2250 F after holding 10 min at temperature.

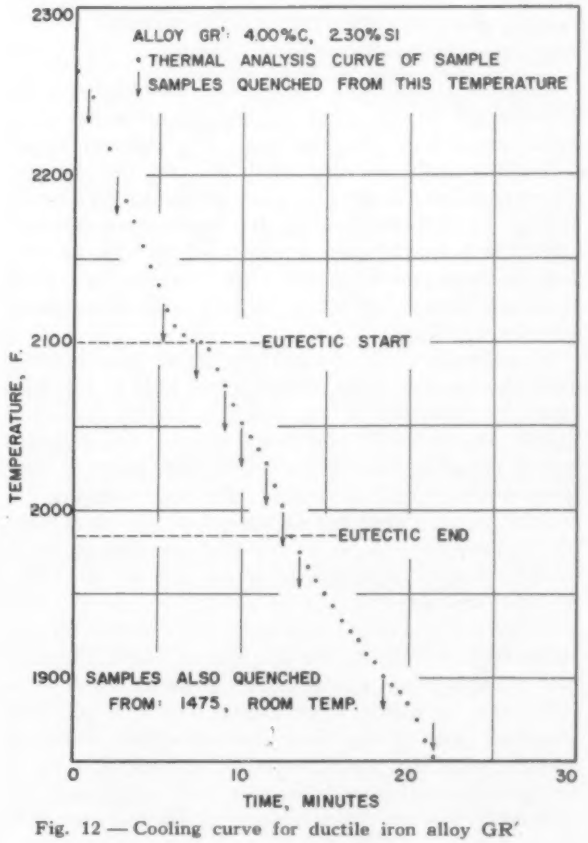

Fig. 12 — Cooling curve for ductile iron alloy GR′

supercooling is not a requirement for the formation of spheroidal graphite. Graphite spheroids have been shown to be developed at temperatures well above the start of solidification of the eutectic, and some of these grow substantially in size early during eutectic solidification. Dormant nuclei grow later in eutectic freezing and at lower temperature. Thus, it should also be noted that the widening of the eutectic solidification range for ductile cast irons is the result of, and not the cause of, solidification of the cast iron with spheroidal graphite.

In summary, the solidification of alloy GR', a hypereutectic ductile iron of 4.0 per cent C and 2.30 per cent Si occurs as:

1. Formation of graphite nuclei beginning at about 2500-2450 F. The nuclei are found imbedded in the carbide of the quenched liquid.
2. Development of graphite spheroids, encased in a thin shell of austenite, from the graphite nuclei. This occurs from about 2210-2200 F down to the eutectic start temperature of 2100 F.
3. Increase in the number of graphite spheroids with decreasing temperature down to 2100 F.
4. Growth of the graphite spheroids without increase in number and the associated growth of the austenite shell thickness between 2100 and 1985 F.
5. Completion of solidification at 1985 F by the above mechanism, and by a gradual increase in the number of dormant spheroids participating in growth.

Other aspects of the solidification of spheroidal graphite cast irons will be taken up later.

HYPOEUTECTIC CAST IRONS

Flake Graphite Irons

An alloy of 3.12 per cent C and 1.70 per cent Si was selected for the study of the solidification of a hypoeutectic flake graphite iron. The thermal analysis cooling curve for this alloy (F) and the temperatures from which samples were quenched are shown in Fig. 13. All samples in this series were held at 2700-2750 F for 10 min before cooling was started. The liquidus, eutectic start, and eutectic end temperatures shown for alloy F were also determined metallographically.

No evidence of any proeutectic phase was observed until the samples were cooled below 2315 F. Furthermore, examination of the carbides in the quenched liquid structure did not reveal any of the graphite nuclei noted in ductile iron alloy GR'. Neither were these nuclei noted in any of the other samples examined at this analysis. Dendrites of the first solid phase, austenite, appeared in the microstructure at 2265 F. These dendrites grew in size as the temperature decreased to 2070 F.

At 2070 F, the eutectic of austenite and flake graphite started to form at several random points throughout the specimen. The graphite flakes in the eutectic cells grew at nearly right angles to the solid-liquid interface with the ends of the graphite flakes in contact with the liquid metal. Photomicrographs of the growth of this eutectic have been presented previously.[15,23,24,49] Therefore no additional ones will be shown here. The sample of alloy F was completely solidified at 2010 F.

Thus, the mechanism of the solidification and graphitization of this hypoeutectic gray cast iron, as determined by this investigation, is in accord with the general consensus of opinion expressed in the literature. In summary, alloy F solidifies in the manner:

1. Solidification of austenite dendrites beginning at about 2315 F and continuing down to 2070 F.
2. Start of eutectic cell formation at 2070 F, resulting in the formation of flake graphite-austenite eutectic cells, which are nucleated on the prior austenite dendrites and grow radially with the flakes of graphite in contact with the liquid.
3. Completion of eutectic solidification by overlapping of the cells at 2010 F.

Spheroidal Graphite Irons

Alloy GSW (3.54% C, 2.14% Si) is a slightly hypoeutectic, magnesium treated, commercially produced ductile cast iron. As such, it was necessary to modify the standard procedure used in this investigation by selecting proper combinations of temperature and exposure time at temperature sufficient to dissolve all graphite spheroids present in the sample. At the same time it was necessary to retain an adequate amount of magnesium to insure solidification of the graphite in a spheroidal form. Table 3 presents data which show the effect of temperature and time on the number of graphite spheroids retained.

Two procedures were therefore used in the study of alloy GSW. The first, used for temperatures from 2700 to 2200 F, involved heating the sample up to the respective temperature, holding for 4 min and then quenching in water. The second, used for temperatures from 2200 F to room temperature, involved heating the sample to 2300 F, holding for 10 min, cooling to the respective temperatures and quenching in water. The techniques were duplicated at 2200 F and produced results which were in complete agreement.

No evidence of any proeutectic phase was evident in the samples quenched from above 2600 F. How-

TABLE 3 — EFFECT OF TEMPERATURE AND TIME FOR DISSOLVING GRAPHITE IN A 3.54 PER CENT C, 2.14 PER CENT Si, MAGNESIUM TREATED DUCTILE CAST IRON

Temperatures at which samples were held, F	Time at Temperature, min	Temperature to which samples were slow cooled, F	No. of Retained Graphite, Spheroids/mm²
2700	4	—	0
2600	4	—	0
2500	4	—	32
2400	4	—	50
2300	4	—	155
2200	4	—	128
2300	10	2200	125
2300	10	2125	82
2300	10	2100	83
2300	10	2070	66
2300	10	2025	65
2300	10	2000	10
2300	10	1900	10

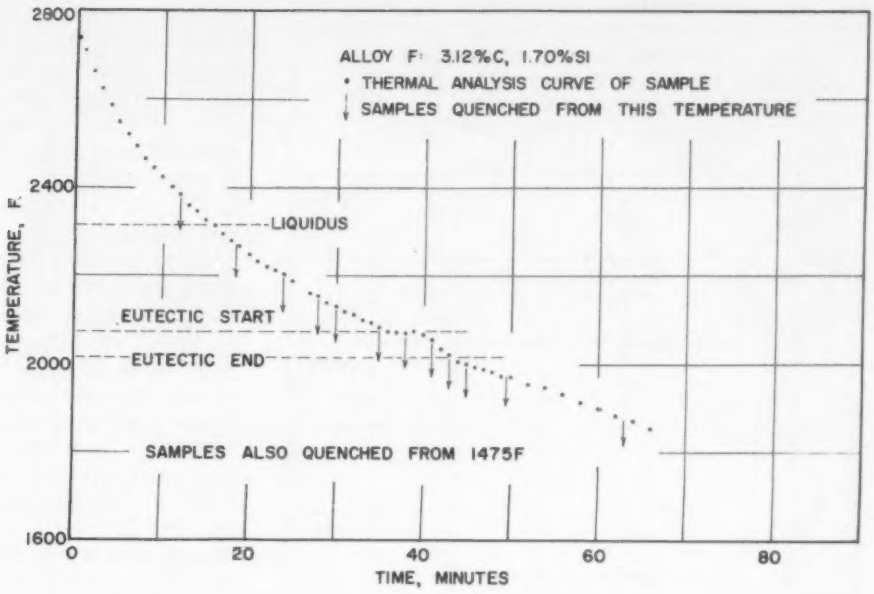

Fig. 13 — Cooling curve for hypoeutectic gray iron alloy F.

ever, at temperatures below 2600 F small graphite nuclei were formed in the carbides of the quenched liquid, identical to those of Figs. 5 and 6 formed in the hypereutectic ductile cast iron. Graphite spheroids were present in all samples obtained at lower temperatures and were surrounded by a shell of austenite, and thus were not in direct contact with the liquid. The effect of temperature on the number of spheroids is shown in Fig. 14. Data using both procedures are presented in this graph which show that the number of spheroids decrease. It may be noted that in alloy GSW, the number of spheroids present continues to decline even during the eutectic freezing range.

The average size of the spheroids increased only slightly with decreasing temperature down to the eutectic temperature, as shown in Fig. 15. During this temperature interval the thickness of the austenite shell surrounding the spheroid remained constant. This austenite envelope was evident even at temperatures where graphite was being re-dissolved into the liquid.

When the eutectic temperature range is approached, solidification may proceed in several ways:

1. By the growth of spheroids according to the mechanism already described in the case of hypereutectic ductile iron.
2. As white iron eutectic.
3. By the nucleation and growth of nonspheroidal forms of graphite such as flakes.
4. By a mixture of the preceding.

Case one, where solidification proceeds with the growth of spheroids, has already been described in connection with a hypereutectic iron. Accordingly, case 3 will be considered, wherein a new flake shaped graphite is nucleated and grows during eutectic solidification. Alloy GSW provides this case.

Eutectic Solidification

Just prior to the beginning of eutectic solidification graphite spheroids are present in alloy GSW, in the number shown at 2115 F in Fig. 14 (about 90 spheroids per sq mm). Solidification of eutectic proceeds both by growth of spheroids and their austenite shells, and by the nucleation and growth of austenite-flake graphite eutectic. The number of spheroids present in the liquid metal was decreased during solidi-

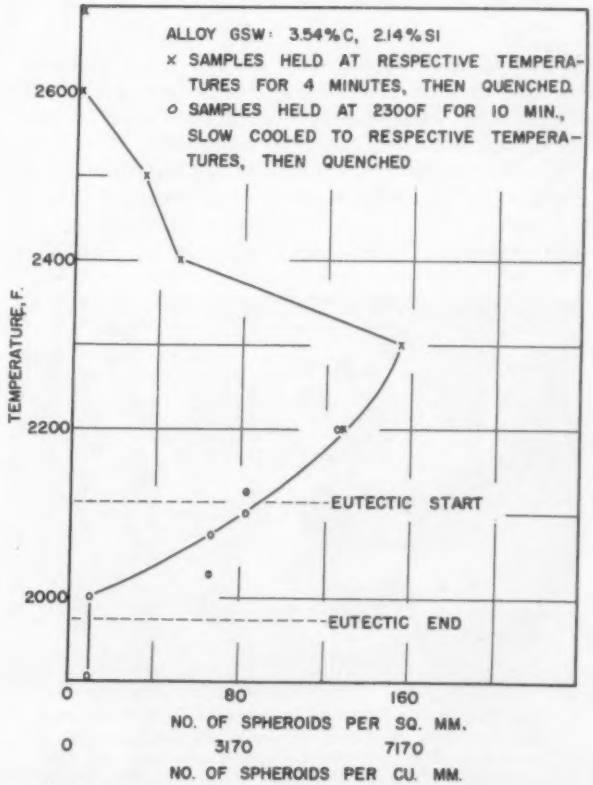

Fig. 14 — Effect of holding melt 4 min at temperature on the number of spheroids retained in the melt. Comparison of number of spheroids is made with samples held 10 min at 2300 F and then cooled.

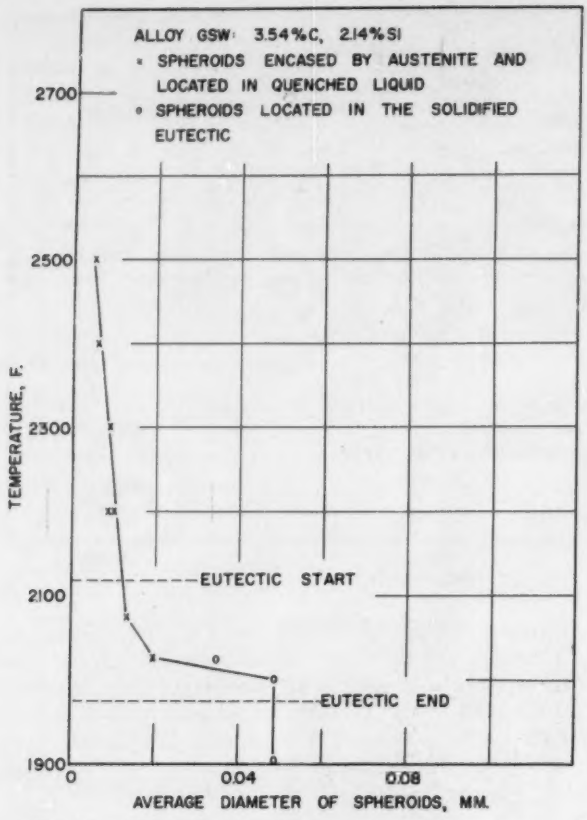

Fig. 15 — Diameter of spheroids as related to temperature of quenching in alloy GSW.

fication of the eutectic, and their average diameter was only slightly increased. This is similar to the observation noted during the solidification of the hypereutectic ductile cast iron, alloy GR′.

The failure of the eutectic to solidify entirely as a spheroidal graphite structure is attributable to both the decreased number of spheroids present at the start of eutectic solidification, and the nucleation of eutectic austenite and flake graphite by the austenite dendrites already present. The nucleation of flake graphite begins at about 2100 F, and is permitted by an insufficient percentage of magnesium in the alloy (Table 1). The combined spheroidal graphite-austenite and flake graphite-austenite eutectics were solidified at 1975 F.

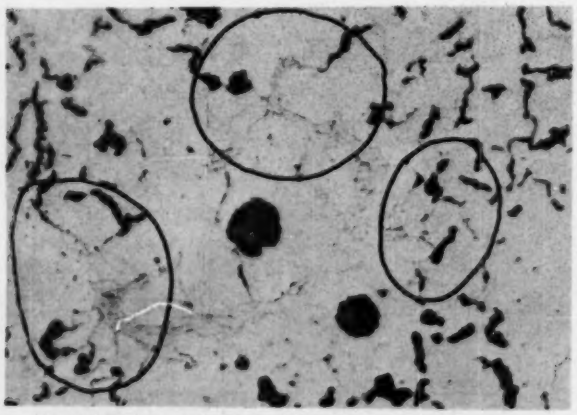

Fig. 16 — Alloy GSW (3.54 per cent C, 2.14 per cent Si) quenched at 200 F, showing the solidification of eutectic both by growth of graphite spheroids and their austenite shells and by growth of austenite-flake graphite eutectic. Encircled areas show flake-shaped graphite growing into unsolidified melt which appears as quenched white iron structure. 2 per cent nital etch. 100 ×.

This dual solidification process provides an excellent example of the difference between the growth of spheroids and flakes. The former are always encased in austenite and do not contact the liquid. The flakes grow with tips protruding into the melt, as shown in Fig. 16. Figure 16 shows the microstructure of a sample quenched from 2000 F. The encircled area shows flake-shaped graphite growing into the unsolidified melt, which appears as a quenched white iron structure.

As with previous samples, the results of thermal analysis (Fig. 17) and microstructural analysis were in close agreement regarding the eutectic start and eutectic end temperatures. Figure 17 also presents the temperatures at which several of the samples, which have already been discussed, were obtained.

In summary, alloy GSW, a slightly hypoeutectic ductile cast iron, solidifies as:

1. Formation of graphite nuclei between 2700 and 2600 F.
2. Development of graphite spheroids from the nuclei between 2600 and 2300 F.
3. Resolution of spheroids by the liquid metal at temperatures below 2300 F.
4. Start of eutectic solidification at about 2115 F as both flake graphite-austenite and spheroid graphite-austenite structures.
5 Completion of solidification at about 1975 F resulting in a mixed flaked graphite and spheroidal graphite structure.

NONEUTECTIC CAST IRONS

Compact Graphite Irons

Two alloys were selected to study for formation of compact graphite. Alloy CS (1.55% C, 2.33% Si) is a commercially produced, as-cast malleable iron in which the graphite is present in the compact shape. Alloy A (0.98% C, 3.52% Si) also contains compact graphite and was reported in a reference.[10] Thermal analysis cooling curves for both alloy A and alloy CS are presented in Figs. 18 and 19, respectively. These graphs also show the temperatures from which samples were obtained following the normal procedure discussed previously and the metallographically determined liquidus and solidus temperatures.

Although the composition of these two alloys are not the same, the mechanism of solidification and graphite formation in them is similar. The two alloys will, therefore, be discussed at the same time. The start of solidification in both of these alloys was accompanied by the appearance of long, thin dendrites in the quenched liquid structure. These dendrites grew in size as the temperature decreased until all of the liquid was consumed. The completely solidified structure of alloy A then consisted of only austenite. Alloy CS contained an extremely small amount of

carbides present as short films in the austenite grain boundaries after solidification was complete. The metallographically determined liquidus and solidus temperatures, respectively, were 2620 and 2120 F for alloy A and 2490 and 2050 F for alloy CS.

No graphite was formed in either of these alloys during the solidification process. During the subsequent cooling after complete solidification the few carbides present in alloy CS decomposed to form small, compact graphite shapes at temperatures below 2000 F. The number and size of these compacts increased as the temperaure was decreased. In alloy A, compact graphite was nucleated at temperatures below 1475 F. This alloy contained less graphite than alloy CS because of its lower carbon content. An example of the type of structure formed in these alloys is shown in Fig. 20. This structure is of alloy CS cooled to room temperature and contains compact graphite in a ferrite plus pearlite matrix.

The presence of compact graphite in cast irons having a carbon content less than the limit soluble in austenite, but which contain at the most only a small amount of carbide after complete solidification, has been discussed previously in a reference,[10] and is shown schematically in Fig. 21. In that work, 4 in. x 4 in. x 8 in. castings were produced of various carbon and silicon contents and were examined metallographically. Compact graphite, as shown in Fig. 22, was noted in samples having carbon and silicon contents just below the maximum solubility of carbon in austenite alloyed with silicon — $\%C + \frac{1}{8}\%Si = 2.0$. Increasing the carbon content caused graphite to appear as long thin films in the microstructure, Fig. 23. Slightly higher carbon contents produced the structure, shown in Fig. 24, where the graphite films have broken down into a transition type of graphite. Eutectic type graphite, Fig. 25, was obtained with slightly higher carbon contents.

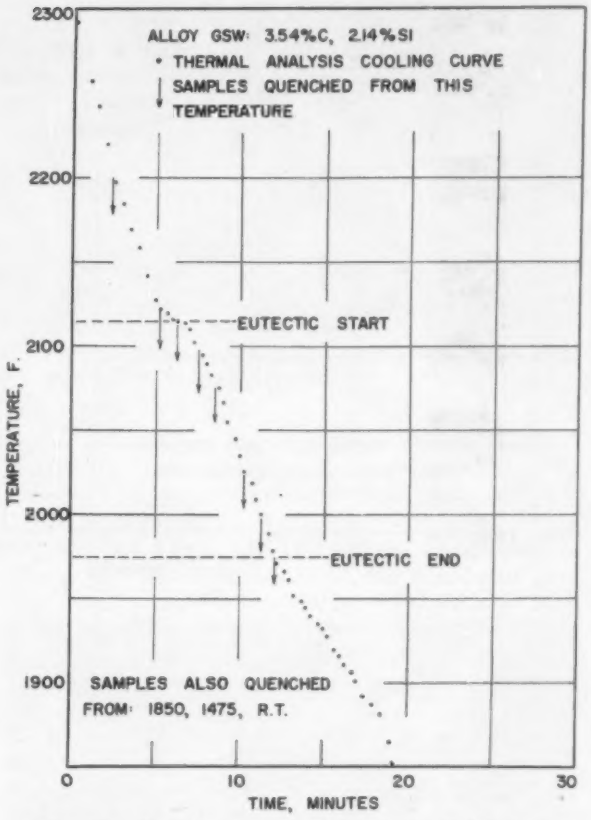

Fig. 17 — Cooling curve for hypoeutectic ductile iron GSW.

Graphite Shape Occurrence

The occurrence of the graphite shapes just mentioned may be discussed in the light of the results obtained from the studies of alloys A and CS. The compact graphite, presented in Fig. 22, was formed in the same manner as that found in alloys A and CS. That is, compact graphite was formed in the solid state by the precipitation of graphite from austenite as the temperature decreased.

With slightly higher carbon contents, a small amount of eutectic is formed. This occurs in the

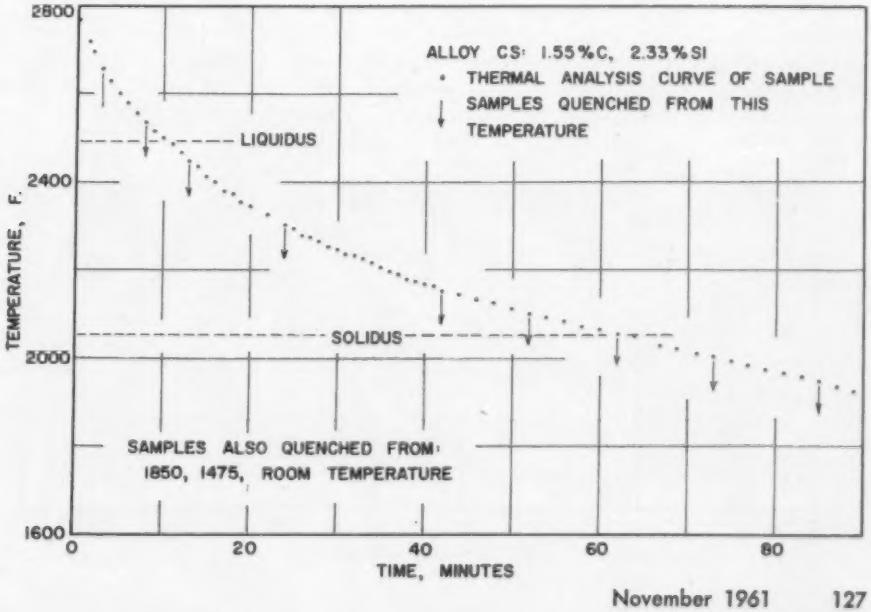

Fig. 18 — Cooling curve for non-eutectic cast iron alloy CS.

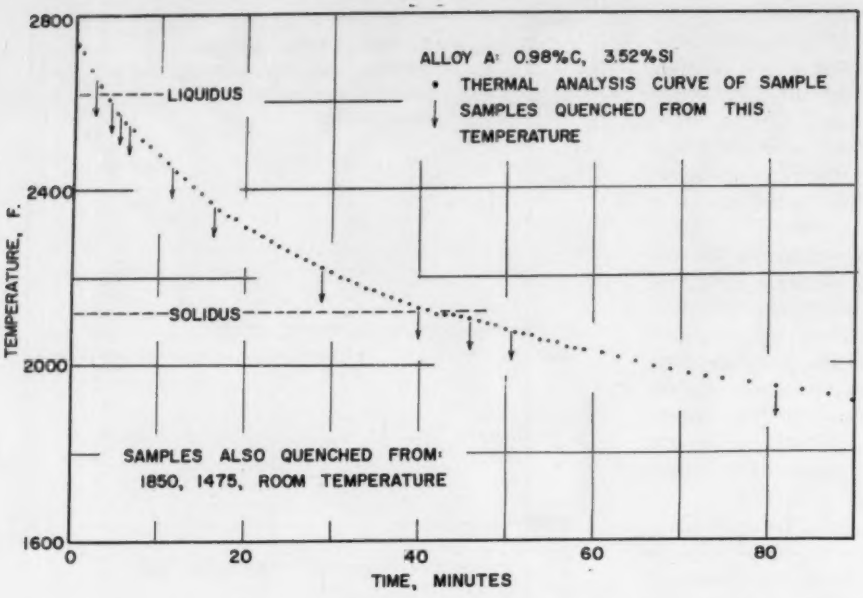

Fig. 19 — Cooling curve for noneutectic cast iron alloy A.

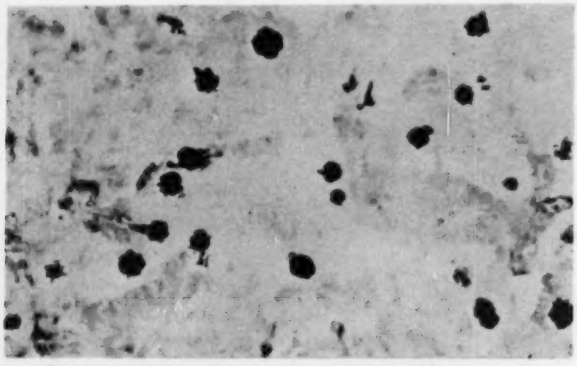

Fig. 20 — Alloy CS (1.55 per cent C, 2.33 per cent Si) containing compact graphite. This sample was furnace cooled to room temperature from 2700 F. The graphite is nucleated and grows in the solid state. 2 per cent nital etch. 100 ×.

cast iron as divorced carbide, and is thus present as films in the austenite grain boundaries. With subsequent cooling of the alloy, these films decompose to graphite, and produce a structure as shown in Fig. 23.

Still higher carbon contents result in the formation of more eutectic in the alloy, and cause the graphite structure, shown in Fig. 24, where the lacy graphite present occurs in areas where the amount of eutectic present between the austenite grains was greater than in other areas, resulting in films. An example of this structure would be at the juncture of austenite grain boundaries. The eutectic type graphite, shown in Fig. 25, is produced at slightly higher carbon contents. This graphite also appears to be the result of the decomposition of carbide.

In summary, the solidification and subsequent graphite formation of alloys A and CS, which contained compact graphite, consisted of the steps:

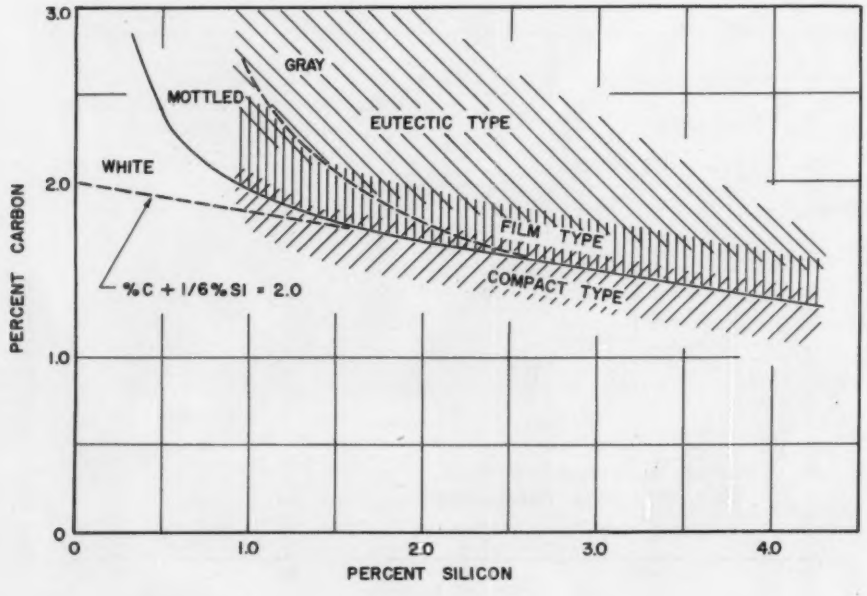

Fig. 21 — Relationship of graphite type to combinations of carbon and silicon percentages approaching the solubility limit of carbon in austenite. The film and compact types of graphite occur in essentially noneutectic compositions.

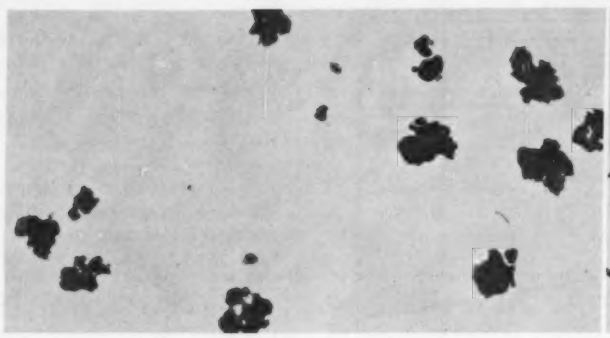

Fig. 22 — Compact graphite of the type occurring at compositions in the area so labelled in Fig. 21.

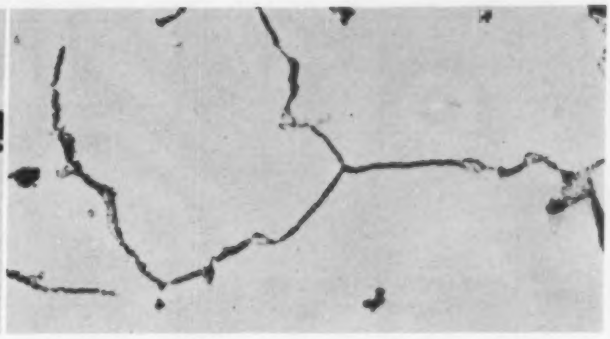

Fig. 23 — Film type graphite occurring in compositions in the area so labelled in Fig. 21.

1. Solidification of the first solid phase at about 2620 F for alloy A and about 2490 F for alloy CS.
2. Completion of solidification at about 2120 F for alloy A and 2050 F for alloy CS. Alloy A was entirely austenite at this temperature while alloy CS contained austenite plus a small amount of divorced carbides.
3. Formation of compact graphite with decreasing temperatures as a result of decomposition of the carbides present and precipitation of graphite from the austenite solid solution.

The formation of films of graphite occurs in cast irons of slightly higher carbon content as a result of the decomposition during cooling of long, thin films of divorced carbides.

Some of the circumstances which prevent the formation of graphite during solidification will now be considered. This is necessary for improved understanding of graphitization during freezing.

Previous work[10] has shown base line curves of limiting carbon and silicon percentages which separate white from mottled and gray fractures. These limiting composition curves hold true under the standard melting conditions described.[10] Figure 26 shows these compositions for a 4 in. x 4 in. x 8 in. block casting. Similar curves for other size castings are given.[10] Further, elements such as tellurium, bismuth, thallium and cerium (and magnesium) are able to shift these curves to higher levels of carbon and silicon when small percentages are added to the iron.

For example, in Fig. 26 the carbon-silicon curve separating white from mottled iron is shown for 0.01 per cent Te addition, as well as for no addition. From these curves it is seen that a cast iron containing 2.60 per cent C and 1.00 per cent Si (also about 0.08% S, 0.05% P and 0.30% Mn) will freeze gray normally, but will freeze white if 0.01 per cent Te is added to the melt. This provides an interesting case where the same base composition may be caused to freeze gray or white without altering cooling rate of the casting. Cooling curves of the casting made in these two cases are shown in Fig. 27. These curves show the expected depression in eutectic temperature range for the white iron as compared with the gray iron of the same composition. The temperatures are 2060 F for the gray iron and 2052 F for the white iron.

Between 0 and 0.01 per cent Te addition, the magnitude of the addition determines whether the casting will freeze gray, mottled or white. From 0 to 0.004 per cent Te addition the casting fracture becomes progressively more white. At 0.004 per cent Te only a few gray mottle specks remain, as illustrated in Fig. 28. These mottle specks are individual eutectic cells (of type A or type E graphite), and their number steadily decreases with increasing Te addition. Finally they disappear at 0.005 per cent addition and the casting is white. Tellurium thus poisons the sites of eutectic cell nucleation. As this occurs, the cooling curve of the casting is progressively altered from that of gray iron to that of white iron, as in Fig. 27. The preceding observations also apply to the effect by bismuth[10] and cerium and magnesium.[48,32]

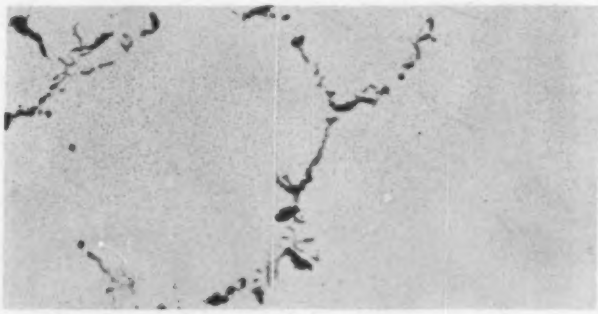

Fig. 24 — Film and eutectic transition graphite in the over lapping areas labelled film and eutectic graphite in Fig. 21.

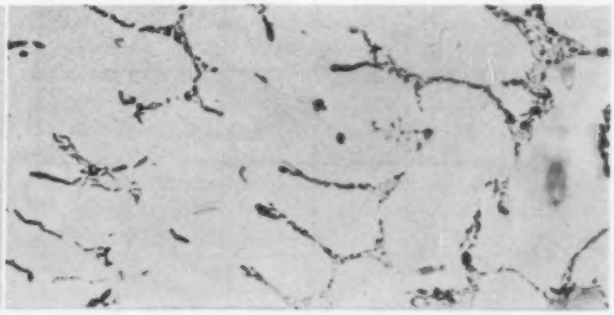

Fig. 25 — Eutectic graphite at carbon percentages slightly above that of Fig. 24, and as related to Fig. 21.

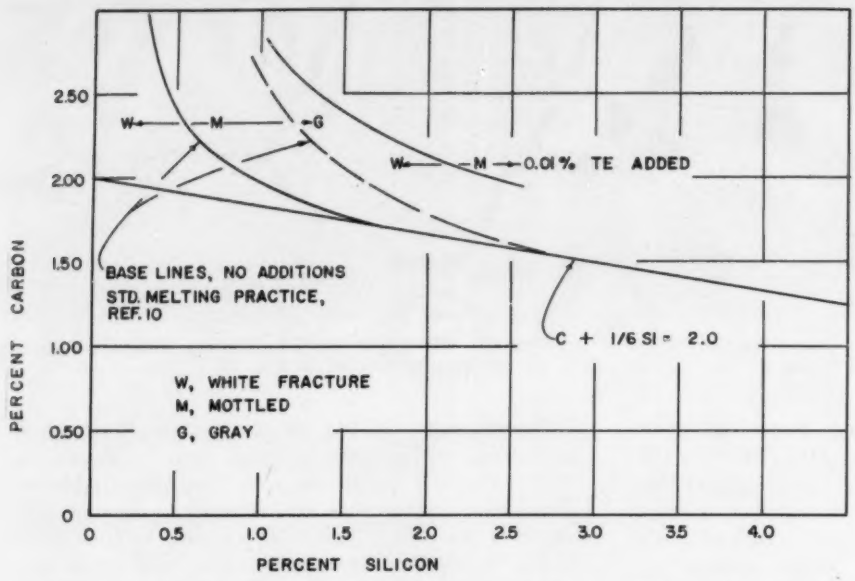

Fig. 26 — Limiting compositions for white, mottled and gray fractures in a 4 x 4 x 8 in. casting without any additions to the melt and with 0.01 per cent Te added.[10]

If the silicon content (or carbon) is now raised above the limit for 0.01 per cent Te addition, a new type of graphitization occurs and a new type of mottling develops (Fig. 29). No eutectic cell specks are visible, and instead the white appearing fracture is flecked with irregular patches of light gray. The cooling curve remains as for white iron. However, the graphite form in the mottle is no longer type A or E, but is as shown in Fig. 30. This graphite is described as lacy, and is frequently intermingled with carbide. Often there is a film of graphite at the carbide interface, as shown in Figs. 30 and 31.

In some areas, type D graphite will be observed, while in other areas what appears to be clusters of flakes exist, as shown in Fig. 31. These types of graphite are the result of poisoning of the normal eutectic cell nuclei, and thus the prevention of graphitization, until the final temperature and moment of solidification or immediately thereafter. This is the reason the cooling curve appears to be the same as that for a white iron. Since the graphitization process appears to be due to the decomposition of carbide, increasing the silicon content of an iron, in which the eutectic cell nuclei are poisoned, is especially effective in producing lacy graphite (and type D) and the irregular mottle of Fig. 29.

As stated previously, bismuth, thallium, cerium and magnesium are elements that have the above effects in varying degree. The general hypothesis for the effectiveness of this class of elements has been advanced.[10] This will now be related to the role of magnesium in ductile irons.

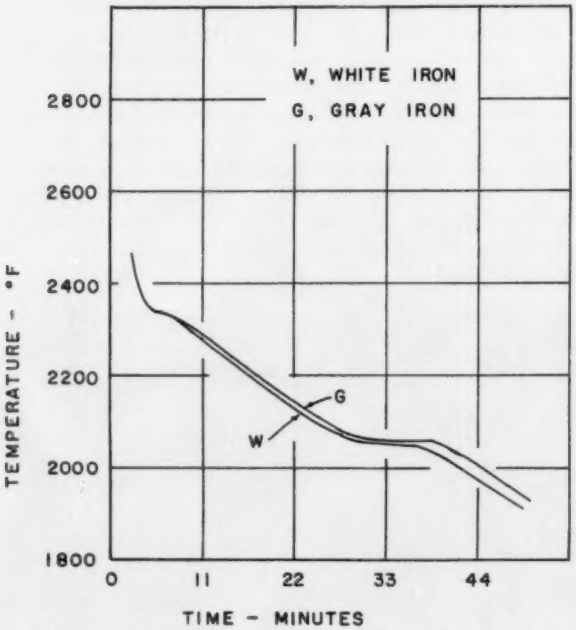

Fig. 27 — Cooling curves for a 4 x 4 x 8 in. block cast iron at 1.0 per cent Si, 2.60 per cent C and cast white at the same analysis but with 0.01 per cent Te added.

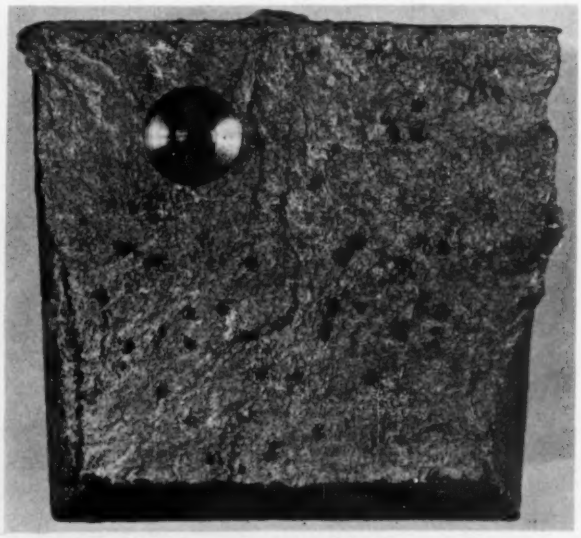

Fig. 28 — Mottle specks in a white fracture when not quite enough Te is added to cause the casting to freeze white.

Since the production of ductile cast iron is based on the addition of magnesium to a low sulfur cast iron, the role of magnesium should be considered with respect to the soldification mechanisms of the various graphite shapes. Magnesium serves a three-fold capacity in ductile cast irons:

1. As a desulfurizer.
2. As a means of providing for graphite nucleation and a wide eutectic freezing range.
3. As a poisoner of eutectic cells.

The fact that magnesium forms sulfides and is a desulfurizer is well established.

In the early stages of the solidification of either hypo or hypereutectic ductile cast irons, graphite nuclei are developed which in turn develop into graphite spheroids. These graphite nuclei are not found in untreated cast irons, but are evident in all ductile cast irons at temperatures below about 2500 F and well above the eutectic solidification range. The role of magnesium in causing these graphite nuclei to form is therefore evident, even though the mechanism has not positively been established. One mechanism which has been proposed is that the nuclei generate within the first carbide to freeze,[33] and therefore are not in contact with the melt.

As the carbide decomposes, a shell of austenite develops which continues to protect the graphite from the melt. The graphite nuclei develop into spheroids of graphite encased in austenite as the eutectic start temperature is approached. If a sufficient number is present at the start of eutectic solidification, the eutectic will solidify by the growth of these spheroids and their accompanying austenite shell. However, if an insufficient number of spheroids is stable at the eutectic start temperature, then the balance of the eutectic will either freeze white or flake graphite will be nucleated, and the eutectic will solidify at least in part as a flake graphite-austenite eutectic.

In order to obtain a completely spherulitic graphite cast iron, it is necessary to nucleate a sufficient number of spheroids and to prevent the formation of other graphite types during the freezing of the eutectic. This is less of a problem in hypereutectic cast irons than hypoeutectic cast irons. In the hypereutectic irons many spheroids can be nucleated, because of both the high carbon content and the temperature range available for nucleation from 2500 F down to just above the eutectic start temperature.

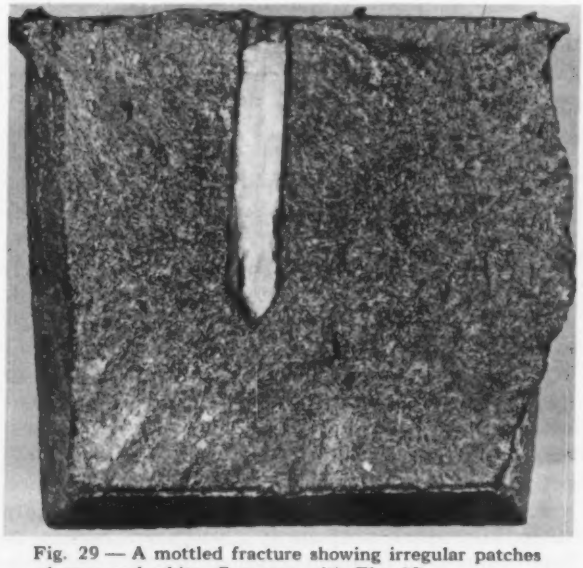

Fig. 29 — A mottled fracture showing irregular patches of gray and white. Compare with Fig. 28.

Fig. 30 — Lacy graphite mixed with carbide, produced in mottled iron with the fracture shown in Fig. 28 and composition just above the limit curve for 0.01 per cent Te added shown in Fig. 26. 2 per cent nital etch. 250 ×.

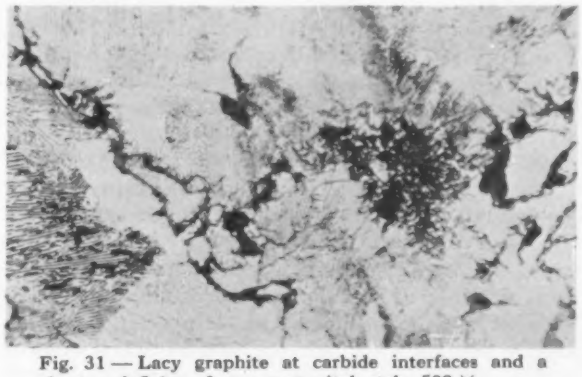

Fig. 31 — Lacy graphite at carbide interfaces and a cluster of flakes. 2 per cent nital etch. 500 ×.

Hypoeutectic Cast Irons

Hypoeutectic cast irons have difficulty providing enough graphite nuclei because the carbon content is lower, and those initially nucleated at temperatures above the eutectic start are not stable and may dissolve above and in the eutectic range. In both carbon ranges, it is necessary in ductile irons to prevent eutectic cell or flake graphite nucleation at or below the eutectic start temperature. This provides the need for the third role of magnesium, which is to prevent the formation of flake graphite in the eutectic freezing range by functioning as a poisoner of eutectic cell or flake graphite nucleation.

In this role, the magnesium functions in the same way as tellurium, bismuth and cerium in the prevention of mottle, as discussed earlier. If insufficient magnesium is present, spheroids may nucleate at the higher temperatures, but eutectic flakes will also be nucleated below 2100 F and mixed graphite types will result in the solidified iron. If the minimum percentage of magnesium is not present, the freezing

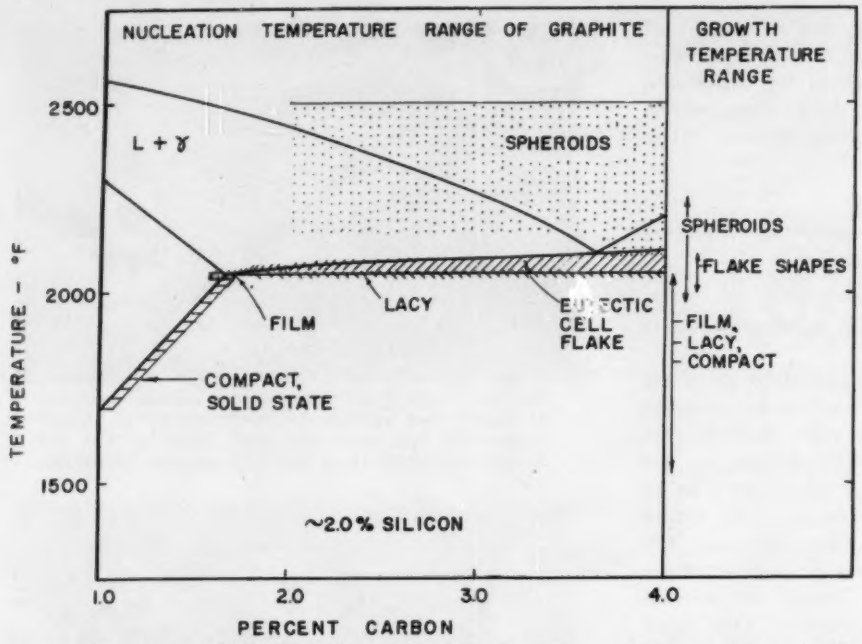

Fig. 32 — Schematic representation of temperature range for nucleation and growth of spheroidal, flake, compact, film and lacy graphite, as related to carbon content at approximately 2.0 per cent Si. Graph is actually semi-quantitative for slowly cooled iron.

range will not start high enough nor be wide enough to nucleate and grow spheroids. The evidence for magnesium raising and extending the eutectic freezing range consists of the thermal analysis data of this report, and the fact that a divorced iron carbide eutectic develops in iron-carbon-magnesium alloys.[27,33]

When an excess of magnesium is present, the tendency is for the final eutectic solidification to proceed as white iron. However, this depends on the silicon percentage present in the iron. It is too high for the magnesium content of the iron, lacy graphite may develop late or at the end of freezing according to the principle discussed previously. Such graphite has been shown to occur in commercial ductile irons, and is reported in the literature a number of times and will therefore not be illustrated here.

In summary, then, magnesium in ductile cast irons functions in at least three ways. First, it reacts with sulfur to permit the second two functions to be fulfilled. Second, it extends the freezing range and permits graphite spheroids to nucleate at high temperatures and grow during cooling. Finally, it inhibits the nucleation of flake graphite in the eutectic solidification range and thereby permits fully spheroidal structures to be obtained.

DISCUSSION

The forms of graphite studied by the authors include spheroidal, eutectic flake, compact, film and lacy graphite. A general theory for the formation of these graphite types can be offered in the light of this and related research. Of primary significance in this theory is the temperature range of nucleation and growth of the various graphite forms. Secondary to the temperature range for nucleation and growth, are the circumstances of chemical composition of the base iron and additions to it which control or modify this temperature range. A semi-quantitative representation of the relationship of nucleation and growth temperature range to composition and temperature for the various graphite forms is shown in Fig. 32.

Temperature of Nucleation and Growth

With reference to Fig. 32, the nucleation and growth of flake graphite as eutectic cells of (γ+ graphite) has been shown to occur in the eutectic solidification range (generally 2100 to 2000 F) by many investigators, as pointed out previously. The authors found agreement with this view in their work. However, this study has not been concerned with the details of the number of eutectic cells nucleated or whether the graphite flakes are type A, B or E. Rather, it has been concerned with the mechanism of growth, which is as eutectic cells of simultaneously solidifying γ+ graphite.

The mechanism involves an interface of solid γ and graphite, with the tip of the graphite flake advancing into the melt from the cell nucleus. Again the authors have not been concerned with the question of whether multiplication of the graphite flakes occurs by branching of graphite flakes, or is initially determined by the number of flakes radiating from the cell nucleus. The essential point concerns the fact that the cells and cell flakes are nucleated and grow over the narrow temperature range of 2100 to 2000 F (or 2100 F to 2040 F in the 2.0-2.40 per cent Si range for type A graphite). Also, the flake grows with its tip in contact with the melt. No graphite flakes or flake nuclei are noted in the melt above the upper eutectic temperature, except in the case of kish in hypereutectic irons.

By contrast, graphite spheroids are nucleated, as shown in Fig. 32, at temperatures of about 2450 to 2500 F down to about 2100 F in both hypo and hypereutectic ductile irons. This is reconcilable in hypereutectic irons but not in hypoeutectic irons where only γ should be present. Nevertheless, this observation was made experimentally. Even in hypereutectic irons, the spheroids were noted to first nucleate at 2400 to 2500 F at the same composition where kish would nucleate at 2200-2250 F. Because of this, it appears a fundamental principle that spheroids

must be nucleated at high temperatures where they are initially stable whether in contact with the melt or not.

A second principle appears to be that graphite nuclei in contact with the melt will grow as flakes, once a temperature between 2200 to 2100 F and lower is reached during cooling. Since spheroids are encased in austenite at these temperatures (or in carbide) they are not in contact with the melt, and may continue to grow as spheroids. Kish nuclei in hypereutectic irons are not encased, and may therefore grow as flakes.

Spheroid Growth

Actual growth of spheroids and the surrounding γ shell begins above the eutectic temperature, is indicated in Fig. 32, and continues rapidly early in the eutectic range, and gradually diminishes as the end of the eutectic freezing is reached at about 1985 F. Growth occurs by adding γ to the shell, and by carbon diffusing through the shell to the graphite sphere. This mechanism of growth is quite different from eutectic cell growth. It is in this mechanism that the added element, such as magnesium or cerium, is helpful by its effect of extending the freezing range of the eutectic. The γ shell is caused to start growing at higher temperatures by this extended freezing range. In addition, the freezing of the eutectic is extended to lower temperatures because the carbide (or graphite dissolved in the melt) is divorced from the γ, depositing on the γ shell surrounding the spheroids.

According to the theory under discussion, these graphite spheroids are nucleated and grow at high temperatures, and are prevented from becoming flakes at lower temperatures by encasement in γ. The boundary temperature is about 2100 F. Below this temperature, graphite nuclei in contact with melt grow as flakes. It follows that if the γ shell encasing the spheroids is ruptured below this temperature, graphite growth then continues by the flake process. This is observed in the exploded graphite emanating from spheroids in commercial ductile irons.

If graphite spheroids are nucleated as a general condition at high temperature, it would also be expected that irons not treated with magnesium or cerium would under some circumstances (quenching, for example) show graphite spheroids retained in the quenched structure. This has also been reported.[15] Also, if spheroids are nucleated at high temperatures in hypoeutectic irons, the graphite should appear in the hypoeutectic dendrites rather than in the eutectic carbide (or flakes). This is also reported.[15]

Further, in ductile irons, it should be necessary to have present an element that will poison eutectic cell nucleation even after graphite spheroids are nucleated. Magnesium performs this function, as does cerium. Bismuth and tellurium can also be used in ductile iron for this purpose. But those elements, such as Te and Bi, which poison eutectic cell nucleation may permit some graphite spheroids nucleated at higher temperature to grow and appear in the solidified iron even without magnesium present. This has been reported,[32] and has been observed by the authors in irons where sulfur has not been below 0.06 per cent and no magnesium was added.

In summary, it is seen that the experimental data plus related observations in a wide variety of cast irons, support the principle that graphite spheroids nucleate and initially grow at higher temperatures than flake graphite, i.e., it is a temperature-dependent phenomenon. This fits the same principle of crystallization of other crystals, such as ice or snow crystals whose shape and growth pattern varies with temperature. With reference to graphite growth, above a temperature of about 2100 F nucleation occurs, and growth is uniform in rate on all axes of the nucleus resulting in a spheroidal form. Below this temperature, nucleation occurs and growth proceeds rapidly on one crystal axis, resulting in flake shapes.

Nucleation and Growth Temperature

Relative to temperature of nucleation and growth, compact graphite has been shown to occur in non-eutectic cast irons where no eutectic is present during solidification, because of the low percentage of carbon in the iron. These compositions are located in Fig. 32. The nucleation of graphite occurs when the metal is in the solid state by precipitation from γ. Growth occurs by diffusion of carbon to the nucleus and precipitation thereon. This requires a gradually decreasing temperature between the solidus and the A_1 transformation temperature of the iron. The term compact graphite is used to describe this form of graphite, and to indicate that it is formed during cooling of the iron from the casting operation. Temper carbon in malleable iron requires reheating after cooling for its formation, and this differs in sequence of formation from compact graphite.

Film and lacy graphite form under conditions which have been amply discussed. However, in connection with temperature of nucleation and growth, as shown on Fig. 32, it should be recognized that this occurs in the lowest temperature of eutectic solidification or by decomposition of carbide just after solidification. This, then, is also a low temperature form of graphite nucleation and growth.

SUMMARY

By combining accurate thermal analysis techniques with quenching of small samples, the authors have studied the freezing mechanism of cast irons containing spheroidal, flake, compact, film and lacy graphite. The work by earlier investigators was confirmed, regarding the mechanism of flake graphite formation by eutectic cell nucleation and solidification in the range of 2100 F and down. Graphite spheroids were shown to nucleate at temperatures of 2400 to 2500 F and to begin growth most significantly in the range of 2200 and down. The mechanism of growth involves solidification of austenite from the eutectic liquid into the austenite shell encasing the graphite nucleus.

The nucleus grows by diffusion of carbon through the γ shell. The mechanism was described for hypoeutectic and hypereutectic compositions. The formation of compact graphite was shown to be a solid state graphitization process in low carbon non-eutec-

tic compositions. Film and lacy graphite were shown to be special cases of low temperature graphitization at temperatures of the end of eutectic solidification or just below, and of special compositions such that no eutectic cells are nucleated. Finally, a general hypothesis has been advanced and supported to the effect that the form of graphite nucleated and grown is primarily temperature dependent with other factors of iron composition and additional elements, functioning primarily through their ability to influence the temperature of nucleation and circumstance of growth.

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NOW...ONE WASH...

*VELVA-PLAST GWA-2

FOR ALL TYPES OF CORES

Surface penetration study reveals a single water-soluble graphite wash* can be used successfully in ferrous foundries on resin-shell, oil-sand and silicate-bonded sands.

These photo-micrographs illustrate the adaptability of VELVA-PLAST GWA-2. Note the varying degrees of penetration into different types of core and mold surfaces, depending upon the composition of the solvent. This unique water-activated coating is exceptionally compatible with alcohol (up to 20% of the weight of the solvent), which materially affects penetration, bonding and drying characteristics.

VELVA-PLAST GWA-2 is an effective refractory at pouring temperatures up to 2800° F. With controlled penetration, inclusions in the casting can be eliminated. Peel is sure, thorough, clean. The new wash remains in suspension and will not settle out. VELVA-PLAST GWA-2 can be applied by swabbing, spraying, or dipping, and is an excellent filler resulting in exceptionally smooth core surfaces.

RESULTS: Regardless of your core composition, you get clean, smooth casting surfaces without a trace of burn-on, and free from penetration defects.

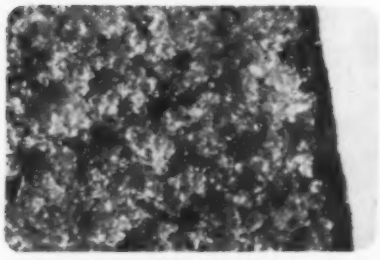

Fig. 1. SHELL CORE coated with VELVA-PLAST GWA-2 mixed with water.

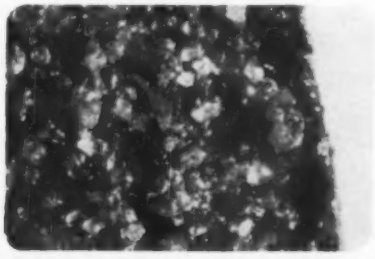

Fig. 3. OIL-SAND CORE coated with VELVA-PLAST GWA-2 mixed with water.

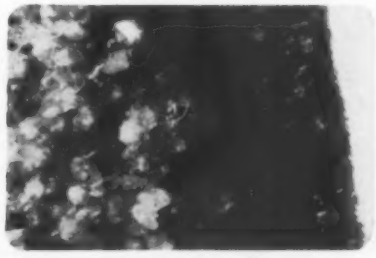

Fig. 5. SILICATE-BONDED CORE coated with VELVA-PLAST GWA-2 mixed with water. Penetration is adequate without use of alcohol.

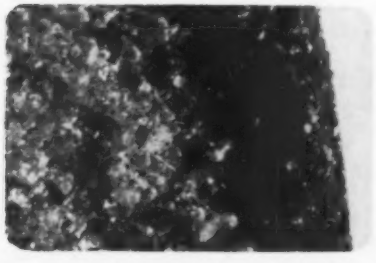

Fig. 2. SHELL CORE coated with VELVA-PLAST GWA-2 suspended in a solution of 80% water and 20% alcohol. Addition of alcohol aids wetting of waxy surface and assures deeper penetration of the wash.

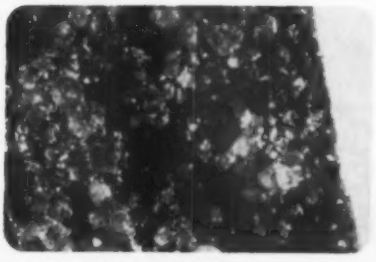

Fig. 4. OIL-SAND CORE coated with VELVA-PLAST GWA-2 suspended in a solution of 80% water and 20% alcohol. Penetration of water-borne wash into surface of oil-sand core is adequate in many instances, but the addition of alcohol speeds up drying of wash.

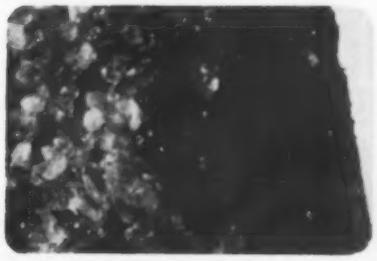

Fig. 6. SILICATE-BONDED CORE coated with VELVA-PLAST GWA-2 suspended in a solution of 80% water and 20% alcohol. The effect of alcohol is evident but would not be required in this case.

* New graphitic refractory wash developed by the ADM Foundry Research Laboratory

Archer-Daniels-Midland

FEDERAL FOUNDRY SUPPLY DIVISION • 2191 West 110th Street • Cleveland 2, Ohio

Circle No. 181, Pages 143-144

AFS Offers Double-Barreled Program Cutting Costs for 1962 Exhibitors

A hard hitting, comprehensive assistance program for exhibitors is now underway by AFS. The two-part program allows the maximum in promotional returns with a minimum of exhibitor expense. Both are designed by AFS Convention and Exhibit Manager Richard J. Hewitt, to give professional aid in areas where exhibitors have asked for assistance.

The first part is "Operation Impact." It is aimed at producing the heaviest attendance at an AFS Exposition. The "Package Display Plan" is designed to lower the cost of exhibiting.

Operation Impact, prepared with the cooperation of the Foundry Equipment Manufacturers' Association, consists of a 10-point program of promotional aids available to exhibitors at no cost. Included are:

POSTAGE METER SLUGS—The message "See You in Detroit" will provide the impact of constant repetion.

ADVERTISING CARDS—Post card size pieces may be used as inserts of individually addressed direct mail pieces.

FOIL STICKERS—Small foil, gummed stickers with a promotional message which may be used on stationery.

AFS PROMOTIONAL PIECES—Direct mail pieces will be used in December, January, February, March, and April. These will go to all AFS members, foundry executives and also distributed in quantity to exhibitors for supplementary mailings.

HOUSING APPLICATIONS — To enable exhibitors to be of assistance to their customers and prospects, housing applications are being supplied to exhibitors for their customers and prospects—in addition to distribution by AFS and its chapters.

THREE LANGUAGE MATERIAL—This is an overseas attendance promotional campaign including three different pieces each printed in French, German, and English. These will be distributed by member associations of the International Committee of Foundry Technical Associations as well as AFS.

GRASS ROOTS BULLETINS—A series of bulletins for exhibitors' field salesmen will be released monthly starting in January to tell of major developments in the Exposition.

CALENDAR CARDS—Wallet size plastic cards with the message about the Congress and Exposition will be available before the first of the year.

NEWS RELEASES—Copies of all news releases concerning exhibitor participation will be made available to companies printing publications.

ART AND TYPE—Exhibitors are being furnished artwork of the IFC-AFS (International Foundry Congress and American Foundrymen's Society) logos and type for imprinting on their own letterheads, ads and promotions.

Special Committee Assists President

A committee of foundry leaders has been appointed to assist AFS President A. L. Hunt in the promotion of the AFS Exposition. This group is known as the President's 1962 Exposition Committee and will form the official inspection committee in addition to its advisory functions.

President Hunt, executive vice-president, Superior Foundry, Inc., Cleveland, is chairman. Other members are:

Norman N. Amrhein, president, Federal Malleable Co., West Allis, Wis.

Elmer Braun, general manager, Central Foundry Div., General Motors Corp., Saginaw, Mich.

Jake Dee, president, Dee Brass Foundry, Inc., Houston, Texas.

William D. Dunn, assistant to president, Oberdorfer Foundries, Inc., Syracuse, N. Y.

L. H. Durdin, president, Dixie Bronze Co., Birmingham, Ala.

Dale Hall, works manager, Oklahoma Steel Castings, Inc., Tulsa, Okla.

Claude E. Jeter, general manager of manufacturing, Ford Motor Co., Dearborn, Mich.

L. R. Kleber, operations vice-president, General Steel Industries, Inc., Granite City, Ill.

Thomas T. Lloyd, executive vice-president, Albion Malleable Iron Co., Albion, Mich.

A. J. Moore, president, Canadian Bronze, Ltd., Montreal, Quebec.

John P. O'Neill, president, Malcolm Foundry Co., Newark, N. J.

Peter E. Rentschler, president, Hamilton Foundry, Inc., Hamilton, Ohio.

Samuel Russell, president, Phoenix Iron Works, Oakland, Calif.

Allen M. Slichter, president, Pelton Steel Casting Co., Milwaukee.

John A. Wagner, president, Wagner Castings Co., Decatur, Ill., and AFS Vice-President.

The committee consists of outstanding foundry executives representing all sections and metals.

Rental Unit Slashes Cost of Exhibiting

Major display problems for AFS Exposition exhibitors have been solved through the renting of special, low-cost, "Porta-Stack" units and furnishings. The plan is possible through the cooperation of the Society's official decorator, Brede, Inc.

This permits the exhibitor who reserves his space early to make his selection of booth interior designs from eight different decorator plans. He will be able to entirely forget about booth preparation, fabrication, erection, and dismantling. Even electrical connections will be made and electricity furnished. He doesn't have to arrive at the exhibit site far ahead of the opening. The booth will be completely decorated.

Booths will have a custom-made header with the company name and address, two spotlights, one fluorescent light, copy panels, and a choice of pegboards for special purposes. Each booth will be carpeted and contain a wide selection of chrome booth furniture, tables, and desks.

The rental charge for this package plan, including erection and dismantling services, electrical connection, booth carpet and furniture—is $3.28 per square foot. This rental fee does not include the floor space cost. The plan is available for all booths 16 feet wide or smaller.

Knight LETTER

NINTH IN A SERIES

To: Foundry Management

Subject: Periodic Engineering Survey

An impartial audit of operations points out where and how a foundry can strengthen its competitive position and more fully utilize its man power and productive capacity.

The rapid development of improvements in techniques, methods and machines means that a foundry considered modern ten years ago may be out of date today. Drawing on the wide experience gained from hundreds of assignments in the foundry field in the United States, Canada, Europe and South America, Knight Engineers are particularly well qualified to help you determine which of the new procedures and equipment can be utilized profitably in your foundry. As professional engineers we are concerned with practical, economical solutions—not influenced by other responsibilities to management or an interest in equipment sales.

A Knight Survey can be helpful to your foundry operation. For further information write or call any of the offices listed below.

Lester B. Knight

KNIGHT SERVICES INCLUDE:

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Lester B. Knight & Associates, G.M.B.H., Berliner Allee 47, Düsseldorf, Germany

NEWS and VIEWS

Highlights from Regionals
AFS Chapter Reports
Meetings for Metalcasters

National Castings Council Co-Sponsors Congress and Exposition in Detroit

Industry-wide support has been assured for the Castings Congress and Exposition to be held in Detroit's Cobo Hall, May 7-11, 1962. For the first time in the history of the American metalcastings industry, the entire National Castings Council of America, comprising the 11 major associations serving the industry, will act as co-sponsors Associations sponsoring the event are:

American Foundrymen's Society
Alloy Casting Institute
Foundry Educational Foundation
Foundry Equipment Manufacturer's Association
Foundry Facings Manufacturers Association
Gray Iron Founders Society
Investment Casting Institute
Malleable Founders Society
National Foundry Association
Non-Ferrous Founders Society
Steel Founders Society of America

The world significance of the Congress and Exposition is emphasized by holding of the 29th International Foundry Congress in Detroit at the same time. The International Congress is sponsored by the International Committee of Foundry Technical Associations comprising the technical organizations of the U.S.A. and the following 21 countries:

Austria, Belgium, Czechoslovakia, Denmark, Finland, France, Germany, Great Britain, Hungary, India, Israel, Italy, Japan, Netherlands, Norway, Poland, Spain, Sweden, Switzerland, U.S.S.R., and Yugoslavia.

This event, held annually in European countries since 1923, was last held in the United States in 1952. The American Foundrymen's Society, sole American member of the International Committee, has been authorized to arrange and supervise the 1962 International Congress. Cast metals experts from all over the world will attend the International and American events at Cobo Hall next May under the theme of "Castings Technology for World Progress." Total attendance of 16,000 is expected.

Name Host Chapter Ladies Entertainment Commtttee

Plans are underway by the Ladies Entertainment Committee of the Host Chapter Convention Committee. This group will have charge of ladies activities at the 66th AFS Castings Congress & Exposition to be held in conjunction with the 29th International Foundry Congress. These events will be held May 7-11 in Detroit's Cobo Hall.

Howard E. Jones, Howard E. Jones, Inc., is chairman of the Ladies Entertainment Committee. Co-chairmen are Mrs. H. E. Jones and Mrs. Harold Gervais. Mrs. Gervais is also assistant secretary of the AFS Detroit Chapter.

Honorary hostesses are: the mesdames Collins Carter, Harry Dietert, Claude Jeter, Tom Lloyd, Clifford Lonnee, C. E. Nelson, Ralph Teetor, and Fred J. Walls.

Hostesses are the mesdames George Abbott, Elmer E. Braun, Wayne Buell, D. L. Buss, Charles Carolin, Glen Cline, Robert Gardner, Harold Grant, J. R. Ikner, George J. Rundblad, T. Schroeder, Ray Sutter, Jess Toth, Roy Vorhees, and M. Warchol.

Two Courses Remain in T&RI Program

Courses on cleaning room operations and production scheduling and control conclude the 1961 AFS-Training & Research Institute program. Both will be held in Chicago at a fee of $60 each.

Cleaning Room Operation, Nov. 1-3. Practical instruction on all phases of cleaning room operation —layout, equipment, purchasing materials, maintenance, ventilation, noise, safety, personnel and production costs.

Production Scheduling and Control, Dec. 4-6. Definitions and analyses of fundamental production problems are presented. Basic understanding and application of production criteria for effective and economical utilization of equipment, materials, and manpower in the production of ferrous and non-ferrous castings are stressed.

Head Detroit Ladies Entertainment Committee

Heading the Detroit Ladies' Entertainment Committee of the Detroit Host Chapter Convention Committee are (left to right) Chairman Howard E. Jones, and co-chairmen Mrs. Howard Jones, and Mrs. Harold Gervais who is assistant secretary of the AFS Detroit Chapter.

Nominating Committee to Select Candidates

A nominating committee to select officers and directors for election at the 1962 Annual Business Meeting was named at the August meeting of the Society's Board of Directors.

Six committee members were elected from lists submitted by chapters eligible this year to suggest members. These six with the two immediate past presidents will meet Dec. 11 at AFS Headquarters, Des Plaines, Ill. They will nominate a president, vice-president, and six directors, endeavoring as prescribed by AFS By-Laws . . . to provide equitable and constant regional representation and . . . representative for the several branches of the casting industry."

Members of the committee are:

Past President N. J. Dunbeck, International Minerals & Chemical Corp., Skokie, Ill., committee chairman.

Past President C. E. Nelson, Dow Chemical Co., Midland, Mich.

Paul Von Colditz, Canadian Steel Foundries, Ltd., Montreal, Que. Representing Region 2 — Chapter Group D, Eastern Canada Chapter —Steel.

William D. Hacker, Jr., Mesta Machine Co., West Homestead, Pa. Representing Region 2 — Chapter Group E, Pittsburgh Chapter — Gray Iron, Steel, Brass and Bronze.

Nard V. Stapf, Greenup, Ky. Representing Region 3 — Chapter Group G, Central Ohio Chapter— Supplies.

Jess Toth, Harry W. Dietert Co., Detroit. Representing Region 4 — Chapter Group H, Detroit Chapter —Supplies.

Ralph M. Stair, General Casting Co., Waukesha, Wis. Representing Region 5—Chapter Group L, Wisconsin Chapter—Gray Iron.

Harry K. McAllister, Western Foundry Co., Portland, Ore. Representing Region 7 — Chapter Group R, Oregon Chapter—Gray Iron.

Ductile Iron Ingot Mold

Paga Molds, Inc., Augusta, Ga., and Greenville, Pa., has signed licensing arrangements with Compagnie de Pont-A-Mousson of France for a patented ingot mold manufacturing process using ductile iron. Paga Molds will handle licensing arrangements in this country.

Large Die Casting Units

Kux Machine Co., Chicago, has recently shipped several die casting machines rated at 1300 tons of die locking force.

Molding Methods and Materials Committee members are engaged in preparing a new AFS handbook. Shown at a recent meeting are Lawrence Winnings, Wagner Castings Co.; guest Guido Brelaz of Australia; guest R. F. Dalton, American Colloid Co.; H. J. Weber, AFS assistant technical director; C. A. Sanders, American Colloid Co.; B. H. Booth, Carpenter Bros., Inc.; guest Ken Echard; R. L. Doelman, Miller & Co., guest Everett Weaver; and W. D. McMillan, Ohio Ferro-Alloys Corp.

Causes and remedies of scrap castings were discussed at a recent AFS-TGRI course held in Chicago. Foundrymen-students were divided into groups to study actual case problems. The course presented an analytical approach to scrap control.

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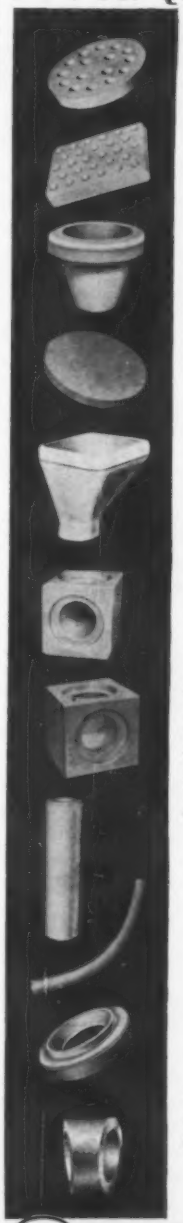
CERAMIC GATING COMPONENTS

. . . For Quality Castings!



Stops rejects and eliminates cleaning room time due to sand inclusions . . . will not spall or erode up to 3250°F. . . . can be returned with the scrap to the cupola without affecting metal composition . . . suitable for all work from small castings in production quantities to 100 ton specials and larger . . . available in the widest range of types and sizes! . . . and volume production has reduced the price on many sizes of Pouring Tubes.

Standards catalog covers 15 types of components.

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Circle No. 184, Pages 143-144

Re-Evaluate Now to Compete in Future Missouri Foundrymen Hear At Regional

Why hasn't casting production kept pace with other segments of the U. S. economy during the past 10 years? Why has foundry production increased only three per cent while the population during this time has risen 20 per cent?

No single answer was advanced at the Missouri Regional Foundry Conference Sept. 21-22 at Rolla, Mo. However, speakers emphasized that now is the time for a re-examination of basic foundry philosophies and an evaluation of conventional and new techniques.

Progress is linked with research, said J. A. Rassenfoss, American Steel Foundries, Chicago. Metalcasters are losing the race to research-based industries because of the small amount of money devoted to research. The amount contributed by metalcasters was described as "infinitesimal." Rassenfoss also condemned the industry for its failure to embrace science and technology as well as its reluctance to support research and to develop new process and products.

Casting salesmen must be customer-minded and not production-minded, pointed out H. M. Randall, International Nickel Co., Houston, Texas. He placed much of the blame on the lack of an aggressive marketing and sales program. He noted that one major job was to overcome the poor reputation castings have made with purchasing agents and design engineers.

Despite the criticisms of the industry, both Rassenfoss and Randall recommended programs by which metalcasters could improve their technological and competitive status.

Industry problems were tackled by T. W. Seaton, American Silica Sand Co., Ottawa, Ill., in this manner—"The problems which we face, we face as an industry and not as individuals. Only through cooperative efforts on the part of all who work in this industry can we meet the challenge of superior quality castings which we are going to be asked to produce. This will require much technical development and research on all our parts."

Today is the time that foundrymen must evaluate the conventional and new techniques. This was emphasized by V. M. Rowell, Archer-Daniels-Midland Co., Cleveland, and Robert Jacoby, St. Louis Coke & Foundry Supply Co., St. Louis. Rowell, in discussing new core developments, said that no one process can solve all coremaking and molding problems. Each has specific applications and should not be adopted without careful study.

Jacoby, in analyzing core practices, stated that more advancements can be made in the coreroom than in other departments. However, he made it clear that each process is only a tool and not a cure-all.

Aluminum foundries producing castings for aircraft and missiles were told by Alan DeRoss, Kaiser Aluminum & Chemicals, Inc., Chicago, that new high-purity, high-strength alloys possess better capabilities. These, he said, are mostly composed of silicon and magnesium and exhibit exceptional high strength after heat treatment.

Other speakers traced foundry problems to a lack of attention and detail. C. A. Sanders, American Colloid Co., Skokie, Ill., stated that sand control still offers the biggest potential in production economy. He added that the human variable still presents a major problem. Unless foundry technology is practiced more thoroughly, he warned, there may be huge losses involved.

Seaton, talking on the same area, stated that much of the difficulty encountered in sand practice is due to a lack of understanding of some of the basic principles of sand technology.

The theme of controls was constantly emphasized. R. L. Riddle told non-ferrous foundrymen: "To maintain and improve the high quality requirements of copper-base alloy castings, it is necessary to install and faithfully follow a program. The factors having the greatest influence on the quality includes design, raw materials, foundry practices, equipment maintenance, and supervision. The best way to discuss a quality control program is to take each of these factors separately and see how each influences quality. Then determine the necessary steps to start and maintain control."

A program for producing ductile iron was advanced by Jeff Green, Sorbo-Mat Process Engineers, St. Louis. It is designed around the control of variables. Four major areas are involved.

Core process are tools not cure-alls, said Robert Jacoby at conference.

New alloys are needed for aircraft and missile uses said Alan DeRoss.

H. O. Merriweather, Lynchburg Foundry Co., Lynchburg, Va., stressed the use and derivation of formulas for improved gating and risering practices. He stated that a better understanding would result in superior castings at lower cost.

Considerable interest was exhibited in new core and mold processes, particularly two processes based on furan resins. These are the chemically cured, self-setting resins for both large coremaking and molding, and the hot-box resins used for high production of cores. These were described by A. Dorfmueller, Archer-Daniels-Midland Co., Victor Rowell, and Robert Jacoby.

AFS President A. L. Hunt gave the response to the welcoming address by Dean Curtis L. Wilson, Missouri School of Mines and Metallurgy. Other speakers and their subjects were: AFS General Manager Wm. W. Maloney, "AFS and You;" B. G. Gray, Air Reduction Co., "Desulfurization of Steel;" Peter Lucido, Kaiser Aluminum & Chemical Co., "Refractories for the Foundry Industry."

Prof. Robert V. Wolf conducted an educational shop course and demonstration on non-destructive testing.

Cutting Costs and Improving Quality Stressed at East Coast Regional

New horizons in metal castings can be achieved by squeezing cost dollars out of every operation and at the same time improving product quality. The blue print for attaining this goal was developed by some 30 metalcasting authorities participating in the East Coast Regional Foundry Conference at New York City, September 22 and 23.

Most of the new developments covered during the 2-day conference involved cost savings, product reliability, quality control, and new technologies. Judging from corridor comments, foundrymen came to learn as much about new developments as possible and many plan to adapt ideas which can be modified to their own individual shops.

Prof. Merton Flemings read M.I.T. Prof. Howard Taylor's penetrating message to management which leveled strong criticism at the foundry industry for failing to attract young blood into their shops. Not enough effort is being made to beam information to designers and customers. Metalcasters consume too much time and energy talking to themselves about their own problems—rather than helping customers solve theirs.

Vernon Patterson, Vanadium Corp. of America, re-emphasized this point in his talk. He presented a round-up of engineering properties available in gray, malleable, and ductile iron, and pointed out the importance of getting this information into the hands of designers and customers.

Save $100,000

How would you like to save $100,000 in cupola operation next year? That's what Beloit Eastern Corp. expects as a result of installing a chip and boring injector on their cupola. Developed in Germany (see MODERN CASTINGS, June, 1958, p. 42) this device uses air pressure to blow inexpensive ($10 - $15/ton) machine shop turnings into the melting zone.

Thinking ahead, William Goessel foresees using this equipment to inject, coke, alloys, and fluxes into the cupola with economies and efficiencies not possible with conventional practices.

The German influence on cupola operations was recognized again when Ralph Clark, Union Carbide Metals Co., praised the virtues of eutectic calcium carbide additions.

By adding amounts equal to two per cent of metal charge, foundrymen benefit from reduced coke consumption, better fluidity, increased carbon, lower sulphur, less pig, more scrap, and faster melting.

If you have ever had trouble with eratic cupola metal analyses then advice from Walter Jaeschke, Whiting Corp., will be most helpful. "By all means avoid developing a 'hang-up' with over-size pieces of scrap," says Jaeschke, "and don't charge thin steel sections unless pressed into bundles."

The subject of temperature gradients come up again in the summary of recent AFS sponsored research by R. W. Ruddle, Foseco, Inc. In the case of red brass, the temperature gradient must exceed 50 F/ inch or unsoundness will result. Since so many brass and bronze castings are used in applications requiring pressure tightness, "leakers" are an expensive cause of scrap. Where temperature gradient cannot be controlled, Ruddle suggests using higher lead contents in certain alloys as a means of gaining sound metal.

As so often is the result, one cure creates another ailment. So with steep gradients the problem of hot tears presents itself. American Brake Shoe Co. approached steel casting improvement through the medium of high purity raw materials. R. J. Ely described their super high strength aerospace steel casting program which reaches levels of 300,000 psi in tensile strength. Using electrolytic iron and other high purity ingredients has virtually eliminated inclusions and hot tears and doubled ductility.

A preview of new horizons in casting metallurgy came when Prof. John Zotos, Northeastern University, described his work in statistically designing alloys for steel castings which will meet individual customer specifications. By using a computer at Watertown Arsenal, 21 foundry variables were inter-related to yield formulas suited to making up steel casting alloys capable of hitting physical property targets established in advance. A complete technical paper will be released on this work.

New mold and core materials continue to make news. Foundrymen will be more competitive than ever now that carbon sand and furan binders are on the market. "The thermal stability and inertness of carbon sand," says E. G. Gentry, Humble Oil & Refining Co., "contributes remarkably to reduction in scabbing, penetration, veining, and burn-on casting defects."

Count on Materials

Foundrymen everywhere are pitting new materials against labor saving. If the added cost of a new material produces greater savings in labor costs and at least equal quality, then it usually receives wide application. Such seems to be the case with the new room-temperature setting furan resin binders. R. M. Ovestrud, Reichold Chemicals, Inc. made this statement: "By having cores chemically harden within 5 to 60 minutes in a wood core box without the need for heat, many savings result—less core rodding, complete elimination of core plates, dryers, and oven baking, less breakage and damage in drawing and handling, and greatly reduced lead time."

Other Gray and Ductile Iron session speakers included: Harish D. Merchant, Owens-Illinois Technical Center; W. C. Jeffery, McWane Cast Iron Pipe Co.; E. A. Welander, John Deere & Co.; Harold Ruf, Grede Foundries, Inc.

Other Steel Session speakers were: Tom Watmough, Armour Research Foundation; G. A. Colligan, United Aircraft Corp.; A. J. Kiesler, General Electric Research Laboratory; W. F. Moore, General Electric Company; Prof. Merton Flemings, M.I.T.

Other Brass & Bronze session speakers were: Herb Scobie, Non-Ferrous Founders' Society; H. F. Gauker, Ajax Magnethermic Corp.; Frank Herlihy, American Brake Shoe Co.; William N. Richards, Deynor Corp.

Other Aluminum & Magnesium Session speakers were: Ray P. Dunn, Lindberg Engineering Co.; John B. LaPota, National Cylinder Gas Co.; E. E. Stonebrook, Alcoa Research Laboratories; Richard Hauser, Bendix Corp.; D. L. LaVelle, American Smelting and Refining Co.

Other Malleable Iron session speakers were: Norman Birch, Albion Malleable Iron Co.; Prof. Richard Schneidewind, University of Michigan; Gordon B. Mannweiler, Eastern Malleable Iron Co.; Carl Joseph, Miller & Co.

Ohio Regional Focuses on Technology Customer Relations for Expansion

Operations for profit with emphasis on techniques and improved customer relations were stressed at the Ohio Regional Foundry Conference held Oct. 5-6 at Cincinnati. Metalcasters, suppliers, and customers recommended a hard look at fundamentals and investigation of new technology.

The metalcasting industry was described by James Voss, Hamilton Foundry Inc., Hamilton, Ohio, as in its most competitive era, taking on other means of fabrication and competing within industry branches as well. His observation reflected the conference outlook.

More castings can be used. Whether or not they will be used is up to the foundrymen. These were the views of two customers participating in a panel of customers, foundries, and trade associations. Representing two large customers were Harry Kindle, Cummins Diesel Engine Co., Columbus, Ind., and S. A. McCarthy, McDonnell Aircraft Corp., St. Louis. Both said that better understanding of customer problems was needed. Both, basically, were concerned with high rejection rates due to defective castings and the lack of dimensional accuracy.

At several points it was demonstrated that customers give the highest consideration to quality, not to price when they evaluate castings. H. F. Scobie, Non-Ferrous Founders' Society, said that recent surveys showed price a poor third to quality and service in customer response.

Ways and means for the industry and individual foundrymen to bring about intelligent and realistic casting specifications were outlined by G. R. Hughes, Ohio Steel Foundry Co., Springfield, Ohio. He advocated education of the engineer in basic foundry practice and improved techniques, explaining that "a higher degree of product performance and cost reductions result when foundry engineers are consulted during the designing stage."

Technical sessions concentrated on the means of developing high quality, uniform castings demanded by customers. Considerable interest was shown in furan-type binders. R. J. Mulligan, Archer-Daniels-Midland Co., Cleveland, outlined the chemistry of the resins. Wayne Buell, Aristo Corp., Detroit, spoke of new techniques and testing methods. He said that AFS committees are working on tentative standards.

Success with furan binders in large work was explained by George Bivans, Standard Steel Works, Burnham, Pa. Cost savings up to 60 per cent were reported with cores weight up to 9000 lb.

J. P. Cummings, International Harvester Co., Indianapolis, outlined results with the hot box process. He said that expanding use was being made at his plant due to quality and speed combined with lower materials cost, uniformity, and easier shakeout.

J. P. Pergler, Ford Motor Co., Cleveland, spoke on design and engineering of hot core boxes. He emphasized that the design must be suited as ideally to the type of machine and planned to provide maximum flexibility.

Stress Fundamentals

Improved surface finish is an important selling point, said James Voss, stating that a poor appearing casting can imply a lack of foundry controls. He emphasized that manufacturers making quality machines demand and will pay for quality castings. Use of fine synthetic sands was credited by George Schultz, Reliable Castings Corp., Cincinnati, for improving quality and finish in a non-ferrous jobbing shop. Synthetic sands, he stated, allow harder ramming of molds giving closer tolerances, and more salable castings through uniformity and improved surface finish.

Patternmakers were warned that they are falling behind on modern techniques. Walter Siebert, Cleveland Standard Pattern Works, stated "there are many trends in the foundry that challenges the patternmaker and only the flexibility and willingness of men can help to achieve better things for our industry. Machined patterns can be competitive said Ray Olson, Southern Precision Pattern Works, Birmingham, Ala.

Concentration of fundamentals were advocated by many speakers. Said David Matter, Ohio Ferro Alloys Corp., Canton, Ohio:

"Foundries should carefully study the available methods of alloying, the available magnesium bearing materials and familiarization with the sound principles of gating and risering.

Simplify Techniques

J. M. Fox, Aluminum Co. of America, Cleveland, spoke on the identification and suggestions for control of inclusions in aluminum alloy castings.

Lack of attention to details or carelessness cause most cupola problems, observed T. E. Barlow, Eastern Clay Products Dept., International Minerals & Chemical Corp., Skokie, Ill. He advocated the intermittent tuyeres with a better understanding of the problems associated with moving bed practice.

J. S. Schumacher, Hill & Griffith Co., Cincinnati, presented a method of evaluating sand to be used in control programs. The method is referred to as the effective clay method. It is based on the amount of new clay that would have to be added to the sand grain fraction to obtain the properties achieved with the original sand.

Jack Caine, foundry consultant, Hill & Griffith Co., presented a paper on dimensioning gating systems for steel castings, written in corroboration with E. H. King and J. S. Schumacher. The paper presented a basic step in developing gating into a predictable system.

Kiss gating of brass castings was explained by C. W. Ward, Jr., American-Standard Corp., Cincinnati. This gating technique has simplified pattern installation of castings designed with draft in one direction so as to mount casting on the drag side of the plate with kiss gating incorporated in the cope with the runner overlapping the casting by 1/32 in. at the mold joint or parting line.

William Johnson, Senango Furnace Co., Dover, Ohio, predicted a continuous increase in vacuum degassing particularly in non-ferrous work where metal is more subject to gas microporosity.

The practical application of statistical quality control in the foundry was explained by Ben Frazer, American Standard Corp., Cincinnati, and Frederick Kasch, Gray Iron Research Institute, Columbus, Ohio, spoke on "Brinell Hardness Variation in Gray Iron Castings." Ralph Davis, Dayton Malleable Iron Co., Ironton Div., Ironton, Ohio, explained practices of heat treatment of malleable and pearlitic iron.

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AFS CHAPTER NEWS

Twin City Chapter

Furan Sand Binders

Mixing methods and cycles for hot and cold curing furan sand binders were discussed by Wayne Buell, Aristo Corp., Detroit.

He pointed out that although furan is a chemical compound that the term furan is now used to name a class of synthetic fast curing binders. Buell pointed out that the furan binder system needs some special rigging such as water-cooled blow plates, heated patterns, and venting. The use of hollow cores was discussed as well as the bench life of the mix. Frank Ryan, St. Paul Brass Foundry, the new Chapter Chairman presided.

F. S. Ryan

The chapter's 16th annual golf outing was held earlier this year. Low gross score for a guest was won by Harry Randolph. Low gross for members was won by Joe Garske, Progress Foundries, Inc. The low net winner was Joe Dragish, Northern Malleable Iron Co. Golf committee members were Gordy Magden, Commutator Co., and Al Blumenthal, R. Lavin & Sons, co-chairmen; Bill Siddons, Smith-Sharpe Co.; Don Marx, Smith-Sharpe Co.; Bob Stenger, Crown Iron Works; Wes Potter, Potter Co.; and Hans Stadem, Stadem Pattern Works.—By Matt Granlund

ST. LOUIS—E. H. Hart, Great Lakes Carbon Co., retiring chairman, right, hands gavel to the new chairman Dale Arnette, Arnette Pattern Co.—by Frank J. Foley

Central Ohio Chapter

Shell Core Practice

Conventional coremaking will increase slightly in the coming years with the hot box process becoming increasingly popular, said Larson Wile, Lynchburg Foundry Co. Wile predicted big gains in the new process will be made at the expense of the present conventional methods. He reviewed current methods and some of the base sands available. Slides were shown of the newer methods of coremaking.—by Russell Marande

L. E. Wile

Northern Illinois-Southern Wisconsin Chapter

Silicoses in Foundries

Industrial cooperation has been a major factor in the reduction of silicosis stated Dr. O. A. Sanders. In addition to the preventive dust control programs, the marked reduction in the incidence of tuberculosis in the general population has also been a factor. Numerous chest x-rays illustrated the great advances made during the past 25-28 years when medical men first became interested in the problem. —by R. A. Oster

TEXAS—F. M. Wittlinger, left, receives the chapter's first certificate of appreciation from Chapter Chairman W. W. Massey. Wittlinger has retired as a director and secretary-treasurer of Texas Electric Steel Co., Houston, Texas, after 34 years service. He was one of the founders of the AFS Texas Chapter, was its first chairman, and served as an AFS National Director. He was also awarded an AFS 50-year pin. Wittlinger has also been active in other technical societies.

NORTHWESTERN PENNSYLVANIA—Members of the entertainment committee were, front row left to right, Jack Green, J. Maskowitz, committee chairman Pete Pascale, chapter chairman Bill Miller. Back row, left to right, John Gordon, Alex Morschauser, and Stan Trenski—by Walter Napp

BRITISH COLUMBIA—Winners in the annual AFS salmon derby included Chapter Chairman J. F. Prior, 3rd; F. Dolman, 2nd; and E. A. Henesey, 1st. The derby was organized by W. Eluck, Mainland Foundry Co., Vancouver.—by J. T. Hornby.

CINCINNATI — Past chairmen were honored recently. Each was given a bronze plaque and a recognition certificate. Shown are Frank Hutchinson, Don Judge, and Joe Schumacher.—by R. Turner

CENTRAL INDIANA — Paul Simmonds, International Harvester Co., Indianapolis, center, exhibits a grin of confidence in casting weight contest. Dick Jacobson, Jacobson Pattern Works, Indianapolis is dubious, and Frank Button, Haynes - Stellite Co., Kokomo, Ind., knows the answer.—by William R. Patrick

WISCONSIN — Forrest Noggle, left, Westover Corp., Milwaukee, outlines standards to control costs to Robert Amrhein, Federal Malleable Co., and Donald Feather, Appleton Electric Co. Noggle addressed the malleable section. — by Bob DeBroux

MEXICO—A dinner honoring Prof. C. C. Sigerfoos, Michigan State University, was given by the chapter for his work in conducting a seven-week foundry seminar under the auspices of the International Cooperation Administration. Shown are Chapter Chairman Francisco Andion; Prof. Sigerfoos; Eugenio D. Aleman, National Chamber of Transformation Industry; George Lindhale. Standing, Estaban Fuchs, Fundidora Panamericana, S.A., seminar coordinator.

San Antonio Section

Outlines Future Program

Three-man panels will be featured at each of the future meetings. Discussions will be conducted on various foundry practices with questions encouraged by the audiences.—by R. L. Thompson, Jr.

Ontario Chapter

Holds Annual Outing

More than 200 members attended the annual outing which included golf, swimming, and other recreation. R.S.M. Gray, Chapter Chairman, Canadian Westinghouse Co., presided.—by J. K. Senior

Central New York Chapter

What's New in the Industry?

New developments in the foundry industry were explained by Jack H. Schaum, editor, MODERN CASTINGS. Schaum stressed that even though the industry is centuries old that technological improvement must continue. He pointed out that competitive industries are also continually adopting new techniques and processes. Chairman Donald C. Brainard, Dayton Oil Co., presided at the first meeting of the technical season attended by 62 members.—by Anthony F. Izzo

J. H. Schaum

TEXAS—Chapter Chairman W. W. Massey, left, presents plaque to outgoing Chairman Edwin A. Schlotzhauer, Jr., American Smelting & Refining Co.—by C. Eugene Silver

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Northeastern Ohio Chapter

Castings—They're Our Business

Since 1945 sales of aluminum permanent mold castings and aluminum die castings have risen 50 and 300 per cent, respectively, while aluminum sand castings have dropped 20 per cent, said Jack Hoover, Aluminum Co. of America. He predicted that by 1964-65 the aluminum foundry industry would produce 165 million lb. of sand castings, 405 million lb. of permanent mold castings, and 600 million lb. of die castings. Charles Walton, Gray Iron Founders' Society, in pointing out the decrease in gray iron castings recommended a 3-point program: a public relations program, a research program, and a marketing program.—by Wallace D. Huskonen

AFS Chapter Meetings

NOVEMBER 10 - DECEMBER 10

Canton District . . Dec. 7 . . Sachenheim Club, Canton, Ohio . . A. B. Sinnett, AFS, *"What AFS Means To You."*

Central Illinois . . Dec. 9 . . Legion Hall, Peoria, Ill. . . *Ladies' Night & Christmas Party.*

Central Indiana . . Dec. 4 . . Athenaeum Club, Indianapolis . . Mervin Horton, Deere & Co., *"Ductile Iron Practice* . . Earle Rearwin, Southern Die & Engineering Co., *"Die Casting Technology."*

Central Ohio . . Nov. 13 . . Maennechor Club, Columbus, Ohio . . H. J. Weber, AFS, *"Safety And Noise Control."*

Chicago . . Dec. 4 . . Chicago Bar Association, Chicago . . Division Meeting . . Gray Iron: G. W. Anselman, Anselman Foundry Services, *"High Pressure Molding."* Equipment Engineering: C. W. Fausel, Chicago Foundry Co., *"A Preventive Maintenance Program."* Steel: Harry Dietert, Harry W. Dietert Co., *"Moldability of Sand."* Non-Ferrous: Charles Ward, American Standard Foundry Div., *"Knife-Gating."*

Cincinnati District . . Nov. 13 . . Eaton Manor, Hamilton, Ohio . . L. J. Pedicini, Lester B. Knight & Assoc., *"Foreign Foundry Engineering."*

Connecticut . . Nov. 28 . . Waverly Inn, Cheshire, Conn. . . Burgess Wallace, Whitehead Bros., *"Sand."*

Corn Belt . . Nov. 17 . . Omaha, Nebr. . . Clyde Sanders, American Colloid Co., *"What European Foundrymen Are Doing."*

Eastern Canada . . Nov. 10 . . Sheraton-Mount Royal Hotel, Montreal . . Panel Discussion, *"Stump The Experts."* . . **Dec. 1** . . Sheraton-Mount Royal Hotel, Montreal, *Past Chairmen's Night & Purchasing Panel.*

Metropolitan . . Dec. 8 . . Military Park Hotel, Newark, N. J. . . *Annual Christmas Party.*

Michiana . . Nov. 13 . . Polish National Alliance Club, South Bend, Ind. . . Ferrous: D. E. Krause, Gray Iron Research Institute, *"Control Tests For The Cupola,"* Non-Ferrous: Michael Bock, II, Exomet, Inc., *"Aluminum, Risering, Feeding, Degassing and Grain Refining."*

Mo-Kan . . Nov. 16 . . Fairfax Airport Restaurant, Kansas City, Kansas, H. J. Weber, AFS, *"Control & Use Of Radiant Heat."* . . **Dec. 2** . . President Hotel, Kansas City, Mo. . . *Christmas Party.*

Northeastern Ohio . . Dec. 8 . . Carter Hotel, Cleveland . . *Christmas Party.*

Northern California . . Nov. 13 . . Spenger's Fish Grotto, Berkeley, Cal., M. K. Young, U. S. Gypsum Co., *"Patternmaking."*

Northern Illinios & Southern Wisconsin . . Nov. 14 . . Beloit Country Club, Beloit, Wis. . . C. T. Jones, National Engineering Co., *"Sand Preparation And Handling For Small Foundries."* **Dec. 2** . . Hotel Faust, Rockford, Ill., *Annual Stag Christmas Dinner.*

Northwestern Pennsylvania . . Nov. 27 . . Amity Inn, Erie, Pa. . . J. A. Westover, Westover Corp., *"Operations Control."* . . **Dec. 2** . . East Erie Turner's Hall, Erie, Pa., *Annual Christmas Party.*

Ontario . . Nov. 17 . . Hotel London, London, Ontario . . *Western Ontario Meeting* . . **Dec. 8** . . Plant Visitation to Stanton Pipes (Canada) Ltd. and Royal Connaught Hotel, Hamilton, Ont., R. A. Clark, Union Carbide Metals Co., *"Use of Low Melting Point Calcium Carbide in the Cupola."* . . J. Morgan, Foseco, Inc., *"Melting Bronze To Meet Hydrostatic Tests and Polishing For Chrome Plating."*

Oregon . . Nov. 15 . . Park Heathman Hotel, Portland, Ore. . . M. K. Young, U. S. Gypsum Co., *"Patternmaking."*

Philadelphia . . Nov. 10 . . Engineers' Club, Philadelphia . . Round Table Discussion on *"Melting."* Brass & Bronze: R. J. Keeley, Ajax Metal Div., H. Kramer & Co., Steel: Harold Kurtz, Empire Steel Castings, Inc., Iron: Clifford Merkert, Olney Foundry Div., Link Belt Co.

Pittsburgh . . Nov. 20 . . Hotel Webster Hall, Pittsburgh, Pa. . . H. F. Scobie, Non-Ferrous Founders' Society, *"What's Wrong With Copper Alloy Casting?"*

Quad City . . Nov. 20 . . LeClaire Hotel, Moline, Ill. . . E. H. King, Hill & Griffith Co., *"Modern Molding Sand & Molding Methods."*

Rochester . . Nov. 14 . . Manger Hotel, Rochester, N. Y.

Saginaw Valley . . Dec. 7 . . Bavarian Inn, Frankenmuth, Mich. . . Group Meetings, Tom Barlow, International Minerals & Chemical Corp., *"Thin Wall Gray Iron Casting."*

Tennessee . . Nov. 17 . . Wimberly Inn, Chattanooga, Tenn.

Texas . . Nov. 17 . . Marshall Hotel, Marshall, Texas . . **Dec. 8** . . Houston Engineering & Scientific Society, Houston, Texas, *Purchasing Agents' Panel.*

Texas-San Antonio Section . . Nov. 20 . . San Antonio Machine & Supply Co.

Timberline . . Nov. 15 . . Engineer's Club, Denver, Colo. . . H. J. Weber, AFS, *"Safety in Preventive Maintenance, Plant Layout, Use of Grinding Wheels."*

Toledo . . Dec. 6 . . Globe Motel, Toledo, Ohio . . William Ball, Jr., R. Lavin & Sons, *"Human Engineering."*

Twin City . . Nov. 14 . . Jax's Cafe, Minneapolis . . George DiSylvestro, American Colloid Co., *"Hot Sands."*

Utah . . Nov. 20 . . Salt Lake City, Utah . . M. K. Young, U. S. Gypsum Co., *"Patternmaking. Design & New Developments."*

Wisconsin . . Nov. 10 . . Schroeder Hotel, Milwaukee . . Steve Denkinger, Milwaukee Chaplet & Supply Co., *"Furfural Cores and Furan Binder Practices,"* Robert Schmitz, Pelton Steel Casting Co., *"Pattern From A Foundry Cost Accounting Viewpoint,"* R. E. Wood, Western Printing and Lithographing Co., *"Quality Control."*

Future Meetings and Exhibits

Nov. 1-3 . . Malleable Founders Society, 12th Annual Market Conference, Hotel Sheraton, Cleveland.

Nov. 13-14 . . Association of Technique De Fonderie. 34th Foundry Congress, Paris, France.

Nov. 13-15 . . Steel Founders' Society of America, Technical & Operating Conference, Cleveland's Hotel Carter, Cleveland.

Nov. 16-17 . . National Foundry Association, 63rd Annual Meeting, Savoy-Hilton Hotel, New York.

Dec. 1 . . Malleable Founders Society, Semi-Annual Meeting, Hotel Sheraton, Cleveland.

Feb. 8-9 . . Wisconsin Regional Foundry Conference, Hotel Schroeder, Milwaukee.

Feb. 15-16 . . Southeastern Regional Foundry Conference, Thomas Jefferson Hotel, Birmingham, Ala.

Feb. 28-Mar. 1 . . Malleable Founders Society, 7th Annual Technical and Operating Conference, Hotel Pick Carter, Cleveland.

March 12-13 . . Steel Founders' Society of America, annual meeting, Drake Hotel, Chicago.

March 15-16 . . Texas Regional Foundry Conference, Menger Hotel, San Antonio, Texas.

May 7-11, 1962 . . AFS 66th Annual Castings Congress and Exposition, In conjunction with The 29th International Foundry Congress . . Cobo Hall . . Detroit.

Metalcasters in the News . . .

E. J. Passman . . . is now sales manager, Charles A. Krause Milling Co., Milwaukee. He was previously foundry sales manager, Frederic B. Stevens, Inc., Detroit.

Kenneth F. Koegler . . . named assistant to the division manager, Doehler-Jarvis Div., National Lead Co., Toledo, Ohio. **John W. Thees** appointed plant manager of Toledo plant No. 2.

J. A. Lombardi . . . named engineer-sales, National Alloy Div., Blaw-Knox Co., Pittsburgh, Pa.

Joseph D. Stank . . . elected vice-president, Ladendorf Co., Detroit. The company represents Casting Engineers, Chicago producer of investment castings.

Arthur F. Uhrlandt . . . named to the newly-created position of director-marketing, Crouse-Hinds Co., Syracuse, N. Y. **F. William Oberle,** succeeds Uhrlandt to the position of director-sales. **Gordon V. Miller,** has been moved to the company's northeast division in New York City.

Richard W. Vollmer . . . appointed to assistant to the president, Strategic Materials Corp., New York.

George K. Dreher . . . is now director of marketing and development, Burnside Steel Foundry Co., Chicago; he was formerly market development director, Steel Founders' Society of America.

Alex Stewart . . . is now a technical sales representative for Algoma Steel Corp., Port Colborne Div.

Daniel E. Lucas . . . appointed eastern regional sales-service manager, Industrial Div., Corn Products Sales Co., and will headquarter at the regional office in New York. He replaces **C. D. Woodburn,** recently named manager of the division's Philadelphia district office.

J. K. Senior . . . formerly general foreman, Canadian General Electric Co., is now foundry metallurgist at Toronto. He is the AFS Ontario Chapter reporter.

Walter Moryto . . . named mechanical assistant to the vice-president of American Steel Foundries' Transportation Equipment Div. He will also continue as manager of the division's service engineering section.

Charles R. Heilig . . . is now manager of furnace product sales for Basic, Inc., Cleveland. **Thomas D. Hess** succeeds Heilig as central district sales manager.

Dr. Conrad A. Parlanti . . . appointed as technical director for General Communication Co., Boston. A molding technique bears his name.

Stanley M. Norwood . . . metallurgist and vice-president of Union Carbide Metals Co., Div. Union

Zircon Sand

Zircon Flour

Get it fast from

BERKSHIRE CHEMICALS Inc.

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Sales Offices: New York • Chicago • Camden • Cleveland • Boston • Pittsburgh • San Francisco

Circle No. 165, Pages 143-144

FOR SALE

BLACK CREEK WISCONSIN

- 4600 square feet
- Railroad switch
- Easily adapted for foundry use
- Priced for quick sale

Inquire:

Philip M. Cornes Company

2722 Eastwood Avenue Evanston, Ill.

DIETERT DETROIT

automation equipment for production sand systems

Sand, Core, Shell and Mold Testing Equipment

CARBON and SULFUR DETERMINATORS

DIETERT DETROIT

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HARRY W. DIETERT CO.

9330 ROSELAWN AVE.

DETROIT 4, MICHIGAN

Circle No. 166, Pages 143-144

Carbide Corp., was honored recently on his retirement.

James B. Johnson . . . supervisor, core department, Hamilton Foundry, Inc., Hamilton, Ohio, has been named "Safety Foreman of the Year" by the Hamilton Safety Council and the Industrial Commission of Ohio. A foreman for the past 25 years, Johnson has never personally suffered a lost time injury nor has any employee directly under his supervision.

Alfred F. Bauer . . . manager, Doehler-Jarvis Div., National Lead Co., has been awarded the Doehler award, highest honor of the American Die Casting Institute.

A. F. Denham . . . president, Denham & Co., advertising and public relations firm in Detroit, has received an honorary degree in Stevens Institute of Technology. Denham & Co., handles promotion and public relations for AFS.

Joe D. Freeman . . . has received the first Service Life membership award by the AFS Birmingham Chapter. Freeman retired in 1960 after 43 continuous years of service with American Brake Shoe Co. He started as an office boy in Birmingham, later becoming a general foreman and superintendent in various American Brake Shoe plants and in 1954 returned to Birmingham as superintendent of the newly constructed plant at Calera, Ala.

Howard C. Gollmar . . . executive vice-president, Elyria Foundry Div., Chromalloy Corp., Elyria, Ohio, has been honored for 50 years service with Elyria Foundry. He started in the pattern shop and worked in various departments until becoming assistant general manager and later head of the foundry. Chromalloy acquired Elyria Foundry in 1957 and Gollmar became an executive vice-president and director of that corporation. He served as chairman of the AFS Northeastern Ohio Chapter.

Deaths

Alfred R. Abelt . . . 71, former vice-president of sales and director of Chain Belt Co., Milwaukee. He had been associated with the company for 51 years.

FASTER, MORE ECONOMICAL SCREENING

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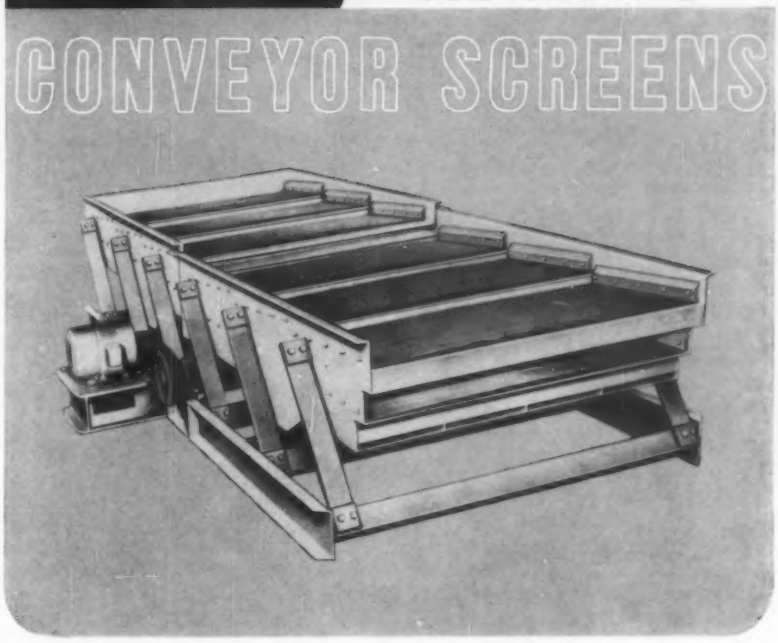
MECHANICAL VIBRATING CONVEYOR SCREENS



Scalp or size and convey bulk materials in one operation. Reduce screen costs.

Syntron Vibrating Conveyor Screens are designed to provide an efficient, effective, and economical method of scalping or screening and conveying sand, ore, castings, and similar bulk materials. Constructed to withstand the wear and abuse of every day operation — built for high capacity screening, long dependable service, and low maintenance.

Syntron manufactures a full line Screen—a style and capacity for every need.

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Other Syntron equipment of proven dependable quality

Vibratory Feeders

Vibrating Screens

Hopper Level Switches

Circle No. 133, Pages 143-144

New Metalcasting Equipment and Processes

What's new in foundry methods and equipment? Summaries of the latest news from manufacturers and suppliers are presented below. For more complete information, circle the corresponding number on the free postcard on page 144. Mail it to us; we'll do the rest.

Hot box accessory . . . produces tensile specimens 1 in. thick for testing after any pre-selected curing time. Specimen made in curing and stripping accessory can be tested while still warm on a sand laboratory universal sand strength machine. Specimens can be allowed to stand for selected intervals to determine the gain in tensile strength with time. Harry W. Dietert Co.

Circle No. 1, Pages 143-144

Shell core blower . . . fully automatic, ejects cores into container or conveyor for direct transfer to molding line or core storage. Adapter plates makes possible a variety of cores. Shell Process, Inc.

Circle No. 2, Pages 143-144

Hollow shell cores . . . can produce 240 cycles per hour with one operator and three machines. Three different size cores with different production cycles can be effected. Beardsley & Piper Div., Pettibone Mulliken Corp.

Circle No. 3, Pages 143-144

Magnesium specifications . . . provides a listing and brief description of the magnesium specifications issued by government procurement agencies and technical societies. Dow Metal Products Co., Dow Chemical Co.

Circle No. 4, Pages 143-144

Foundry products . . . brochure lists six new and eleven standard items with description and prices. G. E. Smith, Inc.

Circle No. 5, Pages 143-144

Trig, log, antilog . . . and log of trig functions 6 place tables are contained in 192 page vest-pocket book. For sale only. Ottenheimer Publishers, Inc.

Circle No. 6, Pages 143-144

Wet or dry blasting machine . . . is offered as wet unit with pneumatic agitator or with pump for high production. Can be converted to dry unit or available as dry machine. Metal Improvement Co.

Circle No. 7, Pages 143-144

Sealer and release agent . . . available in pressurized spray can as well as bulk containers. Acts as sealer or releasing from porous and rough surfaces such as wood, plaster or metal. Furane Plastics, Inc.

Circle No. 8, Pages 143-144

Change pattern letters . . . on metal or wood in less than minute using only screwdriver. Holder is recessed in any pattern including cast iron, aluminum, wood or plastic and held by a lock screw. Freeman Supply Co.

Circle No. 9, Pages 143-144

Electric furnace fume control . . . explained in six-page bulletin. Photographs and sketches show how new exhaust hood, combined with synthetic-fabric dust collector eliminates smoke and fume. Pangorn Corp.

Circle No. 10, Pages 143-144

Infra-red gas burner . . . reportedly has a higher conversion ratio of fuel to infra-red than others. Available with profile adjustment of fuel input for each section permitting control of heat output across full length of burner to adjust for varying heat requirements. Red-Ray Mfg. Co.

Circle No. 11, Pages 143-144

Stacker cranes . . . reportedly combine space savings, load stability, high speed, safety, and reliability. Has stacking height from 3 feet to 20½ feet above the floor. Twin City Monorail.

Circle No. 12, Pages 143-144

for QUICK-AS-A-WINK-
PERMANENT IDENTIFICATION
Every Material...
Every Application!

Markal®
Paintstik MARKERS
Permanent • Fadeproof • Weatherproof

16 Types To Serve You!

ON EVERY SURFACE, marking's easy and lasting when you use Markal Paintstik Markers. No matter whether it's hot or cold, dry or wet or oily—there's a specific type to do the job on metals, wood, plastic, rubber, glass, ceramic, any other surface. To be sure, insist on Markal for your marking requirements.

HOT—Choice of Markal Markers for temperatures high as 2400°F.

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MARKAL—*The Mark of Quality*

MARKAL CO. • 3093 West Carroll Avenue • Chicago 12, Illinois
WRITE TODAY for free Markal Catalog. If you have a marking problem, send details.

Circle No. 163, Pages 143-144

Classified Advertising

For Sale, Help Wanted, Personals, Engineering Service, etc., set solid . . 35c per word, 30 words minimum prepaid. **Positions Wanted** . . 10c per word, 30 words minimum, prepaid. Box number, care of **Modern Castings,** counts as 10 words. **Display Classified** . . Based on per-column width, per inch . . 1-time, $22.00 6-time, $20.00 per insertion; 12-time, $18.00 per insertion; prepaid.

HELP WANTED

Leading manufacturer of foundry facings, supplies and refractories is interested in an aggressive **SALESMAN.** Must have foundry background and selling experience. Must be free to travel. Territory Indiana and Michigan. **Send complete resume to Box K-102 H, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

METALLURGISTS

Metallurgical Engineers with 3 to 5 years experience for evaluation and development of metals for use by large glass company. Applicant should be familiar with metallographic techniques and foundry production methods. Salary commensurate with ability and experience. Work in new laboratory located 35 miles from Chicago in pleasant suburban area. **Write to Mr. R. P. Eichhorn, Hazel-Atlas Glass Division, Continental Can Company, Research & Development Department, Plainfield, Illinois.**

MALLEABLE FOUNDRY & LIAISON MAN —Must be experienced in foundry operations such as pattern layout work, foundry scrap control, and customer service-sales contacts. State age, education, experience, employment records and salary expected. **Box J-103 H, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Illinois.**

MANUFACTURING MANAGER

One of the largest West Coast producers of investment and precision castings offers this challenging opportunity to a man with imagination and drive, plus the ability to get things done.

This position, reporting to the President, has complete responsibility and authority for all production activities.

Excellent salary and benefits, plus growth potential. Applicant must have engineering or metallurgical degree, plus a minimum of three to five years experience as Superintendent, Production Manager, or Manufacturing Manager at a metalworking plant. Experience in investment casting desirable but not required. **Send resume in confidence to Box K-101 H, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

CHEMIST—For Smelting and Refining company to analyze non-ferrous metals and alloys. Modern chemical and spectrographic laboratory. Permanent position. Salary open. Write giving full details on background and ability to: **Box I-103 H, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

PRODUCTION SUPERVISOR

Experienced in alloying, melting, and casting of non-ferrous metals. Metallurgical background desired but will consider equivalent experience. Call or apply in person.

Kawecki Chemical Company
County Line Road Boyertown, Pa.
FOrest 7-2181

MALLEABLE IRON FOUNDRY SUPERINTENDENT, experienced in all phases, to handle complete manufacturing process. **Send resume to Box K-100 H, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

FOUNDRYMEN

when you need SUPERVISORY or TECHNICAL men why not consult a man with actual foundry experience plus 15 years in finding and placing FOUNDRY PERSONNEL

Or if you are a FOUNDRYMAN looking for a new position you will want the advantages of this experience and close contact with employers throughout the country.

For action contact: John Cope

DRAKE PERSONNEL, INC.
29 E. Madison St., Chicago 2, Illinois
Financial 6-8700

MELTING SUPERINTENDENT — Midwest Foundry specializing in stainless steel and high alloy castings needs top caliber young, aggressive, working executive with a minimum of 5 years experience in metal melting. Salary open to negotiation. Send resume. **Stainless Foundry & Engineering, Inc., 5132 North 35th Street, Milwaukee 9, Wisconsin.**

POSITION WANTED

FOUNDRY SUPERVISOR OR CORE ROOM FOREMAN position wanted. 24 years experience in gray, ductile and alloyed iron castings. Thoroughly experienced in all types of core making, including last ten years as Core Room and Molding Foreman and as Foundry Supervisor. Age 46, and married. **Box K-103 P, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

MANAGEMENT POSITION sought by experienced (17 years) Metallurgist, well rounded in arc and induction melting all steels, molding, processing, heat treating, estimating and casting design. **Reply c/o Box J-105 P, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

GRADUATE METALLURGIST, with supervisory experience carbon, alloy and stainless steels, molding, melting, processing and heat treating, seeks broader horizons. **Address: Box I-105 P, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

FOR SALE

FOR SALE—One Model 2½F Simpson Mix-Muller, approximately 40 cu. ft. capacity, complete with dust hood and 60 HP motor. Excellent condition. Used 3 years. **Address Box I-107 S, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

QUALITY EQUIPMENT
SAVE AT LEAST 50%

Blast Cleaning
15" cont. Wheelabrator Tumblast
36" x 42" Wheelabrator Tumblast
18GN Pangborn Blastmaster Late
Furnaces
3000# Detroit Ind. Arc. Mltg.
210 KW Lindberg Heat Treat
1½ Ton Arc Melting Furnace
500# Induction Melting Inst.
Sand Mullers
Simpson #3, U.D., 30 cu. ft.
Simpson #2, U.D., 14 cu. ft.

Complete stock of foundry equipment. Send for free illustrated catalog.

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Foundry Sand Engineer
Consulting . . . Testing
14611 Fenkell (5-Mile Rd.)
Detroit 27, Michigan
Res. Phone **VErmont 5-8724**

Die Casters Elect Brown

Officers and directors of the American Die Casting Institute were elected at the 1961 annual meeting held in Chicago. Officers are president, Walter E. Brown, Kiowa Corp., Marshalltown, Iowa, and vice-president, W. G. Newton, Jr., Newton-New Haven Co.

Elected to three year terms to the board of directors are: Alfred Schneier, Jr., Advance Pressure Castings Corp.; R. I. Kopper, Monarch Aluminum Mfg. Co.; R. C. Shirtum, St. Louis Diecasting Corp.; and Frank Yaussi, Ambrit Industries. W. N. Brammer, Precision Castings Co., Div. Fulton Industries, Inc., was elected to complete the unexpired term of A. D. Weigolt.

Directors at large serving one year terms are: W. E. Brown, executive vice-president; F. W. Burgie, Doehler-Jarvis Div., National Lead Co.; T. E. Coleman, Madison-Kipp Corp.; and R. A. Peters, New Products Corp.

Shipments of die castings of all metals for the first half of 1961 fell short of the 1960 figures for that period. However a slow steady improvement since that time indicates that the production of aluminum die castings for the full year may top the 1960 output of 365,-500,000 pounds and zinc die casting production will fall short of the 1960 level of 312,500 tons by about 10 per cent.

The Editor's Forum . . . . .

Soon to be announced . . . details on the new cooling curve technique for quickly determining the carbon equivalent of gray iron at the cupola. Dan Krause at Gray Iron Research Foundation has been working eight years perfecting this important breakthrough. He now has about 10 foundries using the test regularly as a new quality control tool.

Since carbon equivalent (% carbon plus ⅓% silicon) is an accurate function of freezing point of gray iron, it is a relatively simple matter to record a cooling curve and notice the liquidus temperature—marked by a change in slope on the curve. A reference chart converts liquidus point to carbon equivalent.

The test takes two minutes, a core sand mold, a thermocouple, and temperature recorder. A quick carbon determination can also be run thus giving you the silicon content by difference. One Ohio foundry I visited recently finds the test helpful in holding carbon equivalents in the range of 4.05 - 4.25.

We see this as a new technical development which will raise quality by speeding the controls of an important variable.

Automatic grease monkey . . . lubricates 2500 different bearings every 4 to 8 hours at Louisville Foundry of American Radiator & Standard Sanitary Corp. Allan Nuss, foundry engineer, convinced management that the system would pay for itself by savings in maintenance labor, fewer breakdowns, and longer equipment life. Somehow those hard-to-get-at grease fittings are easily forgotten until a bearing burns out or shaft freezes. Foundry equipment operates in one of the most abrasive industrial environments in existence. Generous and frequent applications of grease and oil from a central system is one of the most reliable preventive maintenance practices available today.

Profitable operations . . . are the result of team-work between management and all the other employees in the plant. This is often the intangible difference that separates the 5-day week shops from the 3-day operations. Midwest Foundry at Coldwater, Michigan, does a good job of communicating this important inter-relationship. As you enter the main entrance into the foundry your attention is immediately attracted to this message which covers an entire wall:

Doesn't it seem good to be working steady again? Did you ever wonder why?

1. We have an effective sales organization and they are selling more castings.
2. You are helping them sell by producing a better casting.
3. We can again sell our products at a competitive price because —
   - A. You are making less scrap.
   - B. Because of less scrap we have less labor in the good castings we make.
   - C. Because of less labor cost we can sell for less than other foundries.
   - D. Because we sell for less we sell more.
4. Because we sell more—we work more.
5. If we work more—we buy more.
6. If we buy more—our customers buy more and we again work more.

It's no secret that is why you are working today.

Now
Let's Keep Competitive
Let's Keep Selling
Let's Keep Working
Let's Keep Buying

Albert H. Doerr
General Manager
Midwest Foundry Co.
Coldwater, Mich.

Market Opportunity? Why not cast gray iron burial vaults. One prominent foundry sees a possible market for 150,000 a year.

Jack Hickam

METALGRAMS

UNION CARBIDE METALS

. . . news of "Electromet" ferroalloys and metals

NOVEMBER 1961

FOR HOT, FLUID IRON -- "EM" foundry carbide, a new exothermic material added to the cupola, produces hot, fluid iron with no initial investment in hot-blast equipment. One per cent foundry carbide by weight of the metal charge raises iron temperatures by 50 to 60 deg. F. Two per cent adds 100 deg. F. The carbide also helps produce hot cupola startups and rapid temperature recoveries after shutdowns.

* * *

HIGHER QUALITY IRON, LOWER COSTS -- By making iron more fluid, "EM" foundry carbide improves castability. Slag separation is also more complete. Castings are less likely to have gas defects, unsoundness, and chilled corners. The high temperatures produced by foundry carbide eliminate bridging and promote trouble-free melting. Since silicon recoveries and carbon pickup also improve, large amounts of steel scrap and other low-cost materials can be charged. Thus, foundry carbide allows savings in material costs. Write for booklet F-61-0119.

* * *

DUCTILITY AND IMPACT PROPERTIES IMPROVED -- Nearly all carbon steel foundries deoxidize with aluminum. In so doing, some Type II intergranular sulphide inclusions usually form. These sulphides give poor tensile bar fractures, with low reduction-in-area values. They also lower impact strength. When calcium-silicon or calcium-manganese-silicon is added with aluminum, random Type III sulphide inclusions form. Since Type III inclusions have much less effect on properties than Type II, ductility and impact values will be higher. For information on how one foundry uses calcium-manganese-silicon to obtain extremely high properties, write for the article, "Ca-Mn-Si Boosts Casting Quality," in the Winter-Spring 1961 issue of UNION CARBIDE METALS REVIEW.

* * *

INTEREST IN COLUMBIUM STEELS GROWS -- For many years, columbium has been used to (1) prevent intergranular corrosion of 18-8 stainless steels, allowing welding; (2) reduce air hardening in plain-chromium stainless steels; and (3) increase the high-temperature strength of high-alloy compositions. Further information on these uses can be obtained by writing for booklet F-20,113 or circling 000 on page 00. Recently, many foundrymen have shown interest in the improved strength and weldability of mild-carbon steels, obtained by wrought producers, by adding up to 0.03 per cent columbium. Information on these steels can be obtained by writing for the article, "Columbium in Carbon Steels," in the Fall 1961 issue of UNION CARBIDE METALS REVIEW or circling 168 on pages 143-144.

* * *

UNION CARBIDE METALS COMPANY, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y. In Canada: Union Carbide Canada Ltd., Toronto.

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In 10 years, National has brought sand reclamation of age.

Every day thousands of dollars are being saved in our foundry industry.

...because 70 National units are in use.

Your 1961 National system will come complete with classifier, rotary screen and individual cell controls.

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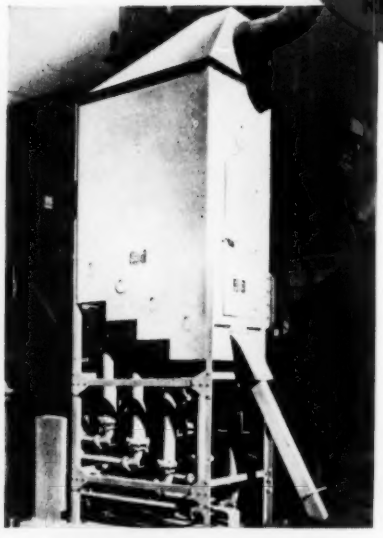
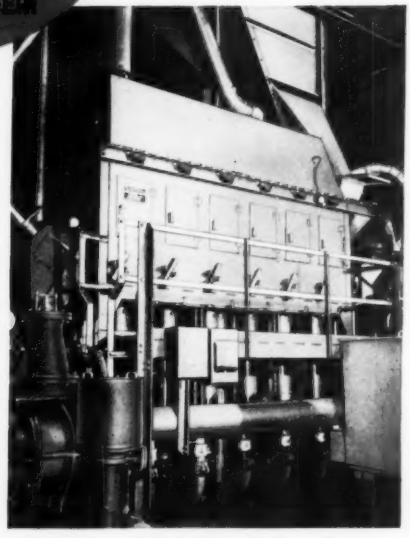
RECLAIMING SYSTEM



1951: A Sand Scrubber unit



TODAY: An integrated Sand Reclaiming System.

Foundrymen who are aggressively waging the battle of profit vs. cost are winning with the National System.

There is a unit near you . . . Ask your National agent to show it to you . . . Write for literature.

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